

II. THE TROPIDOLEPTUS FAUNA AT CANANDAIGUA LAKE, NEW YORK, WITH THE ONTOGENY OF TWENTY SPECIES.

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GENERAL INTRODUCTION.

The present paper is composed of two distinct parts, the first part being of a biological nature, and representing the results of work done at the Yale University Museum under the late Professor Beecher ; and the second a faunal paper, prepared under the direction of Professor Williams, also at Yale.

An abstract of the first part of the paper giving the more general results in condensed form, was published in the *American Journal of Science*, Vol. XVII, April, 1904. The details are now presented, illustrated by about forty figures and one plate in addition to those which accompanied the abstract, and several species are here discussed, which were not touched upon in the previous paper.

I wish to acknowledge my indebtedness to that great paleontologist, Dr. C. E. Beecher, not only for his guidance in the preparation of this paper, but for his help and continual inspiration for work in the field of research. The figures are the work of Mr. Sidney Prentice, draughtsman in the Section of Paleontology at the Carnegie Museum. Most of them are from camera lucida sketches. The plates are from photographs taken by Professor Beecher and the writer.

A set of the specimens on which the first part of the paper is based has been deposited by the writer in the Carnegie Museum, and figures 1-3, 5-12, 14, 15, 24, 26-29, 33, 34, 42-45, 47-48 are drawn from individuals in this collection. The series represented in the plates are the property of the Yale University Museum.

PART I. ON THE DEVELOPMENTAL CHANGES OF SOME OF THE COMMON DEVONIAN BRACHIOPODS.

INTRODUCTION.

Certain layers of impure, clayey limestone from the Moscow (Hamilton) shales in a ravine near Canandaigua Lake, N. Y., were found

by Dr. John M. Clarke to contain fossils, whose shells had been so completely replaced by silica, that, when the rock was etched in acid, the shells were left in as perfect condition as they were when buried in the limey clay of their native sea-bottom. A large quantity of the material was obtained by Professor C. E. Beecher and through his kindness the writer was given an opportunity to study a part of it. About sixty-five pounds of this rock was treated with hydrochloric acid and the shells separated by washing from the clay which remained after the calcium carbonate had been removed. About fifteen thousand nearly perfect specimens were selected and a much greater quantity of fragmentary material discarded. Nearly all classes of invertebrate animals were represented in this collection, but the brachiopods were most numerous, composing fully two-thirds of the total number of individuals. There are as many as thirty-five hundred specimens of one species (*Chonetes scitulus*). Next in abundance to the brachiopods were the Bryozoa, then the Crustacea, worm tubes, Pelycypoda, Gastropoda, Anthozoa, and Cephalopoda in the order named. The Echinoderms are represented only by crinoid columns. There were also a few fish scales and sponge spicules found. Chitinous shells of the *Lingula* type do not appear to have been preserved and some of the Dimyarian bivalves occur only as casts.

The majority of the shells are white, but some are dark gray to black and the trilobite tests are light to dark brown. The color seems to be fairly uniform for all the individuals of the same species. For instance, there are two species of *Monotrypa*, and all the individuals of both species are black, while most of the Bryozoa are light colored. But in the case of *Chonetes mucronatus*, whereas most of the specimens are dark, a few are light.

The state of preservation of the fossils in this material is remarkable, even the finest details being retained, which shows conclusively that the shells were not subjected to any rough wave action after the death of the animal. The graceful fronds of the Fenestellidæ are obtained as they grew, and the delicate spines of the Productidæ and the spiniform extensions of the cardinal angles of the young Stropheodontas are perfectly preserved. Unfortunately the brachial loops and spires are not so well preserved, though many specimens of *Eunella* show a large part of the loop and in one young specimen it is entire. Many specimens of *Tropidoleptus* retain the delicate median septum and the crura but the full loop was not observed.

Perfect specimens of the little Ostracods of the genera *Hallictella* and *Kirkhyra*, whose shells are merely a fine network, were obtained, and also many of the Rhombopora-like Bryozoa covered with minute spinules.

The pelecypods, which are nearly all immature individuals, are excellently preserved, and many of them retain the prodissoconch.

The advantage of this method of collecting is shown in the great number of specimens of supposedly rare species obtained. *Pholidops hamiltoniae*, which is rare in ordinary collections, is extremely abundant in this material, only one species being more common. *Pholidops oblates*, of which not more than a dozen specimens have been obtained from other localities, has been obtained by the hundreds. *Ascidodictyon stellatum*, *Autodetus lindstrami*, and the Ostracods, which are rarely found in any quantities, are here very common.

The whole fauna consists of about 115 species so far identified and 10 or 12 species whose specific identity is uncertain, some of them probably new. The fauna is distributed as follows, Crustacea : Trilobita, 5 species ; Ostracoda, 11 species ; Cephalopoda, 1 species ; Gastropoda, 8 species ; Pteropoda, 3 species ; Pelecypoda, 16 species ; Brachiopoda, 38 species ; Bryozoa, 18 species ; Vermes, 6 species ; Anthozoa, 5 species.

A large proportion of the individuals of the Brachiopoda are in immature stages, many of them being less than one millimeter in length and there are specimens showing all gradations in size up to the adult, and in many cases, to the senile conditions. Series showing all these stages were picked out whenever possible, and carefully studied to ascertain what changes took place during the lives of the individuals of the various species.

The pioneer work of this sort was done by Beecher and Clarke on material obtained from Waldron, Indiana. In the memoir which they published giving the result of this work, the development of 25 species, belonging to 18 genera, was described. Later work by Beecher, Schuchert, and Cumings has added a full description of several more. Among the fossil Brachiopoda, two genera of the Rhynchonellidæ, three of the Atrypidæ, two of the Spiriferidæ, three of the Athyridæ, one of the Cranidæ, one of the Eichwaldidæ, four of the Strophomenidæ, four of the Orthidæ, and one of the Porambonitidæ, have been studied in this way up to the present time.

In the present paper the full series of changes are described for twenty other species and notes are made on four more. In this

list there are fifteen genera, eleven of which are not represented by the work previously done. These genera belong to the families Centronellidæ (*Trigeria*), Terebratulidæ (*Eunella*), Teretratellidæ (*Tropidoleptus*), Spiriferidæ (*Cyrtina*, *Delthyris*), Cranidæ (*Pholidops*, *Craniella*), Strophomenidæ (*Stropheodonta*, *Pholidostrophia*), and Productidae (*Chonetes*, *Strophalosia*). The genera *Crania*, *Rhipidomella*, *Spirifer* and *Orthothetes* are here represented by middle Devonian species, while the previous work was done on Silurian species, and interesting points may be obtained by comparison.

The following list shows which of the brachiopods that occur in this material furnished series suitable for study.

Camarotoechia congregata (Conrad). Two specimens, both adults.

C. horsfordi Hall. One specimen, an adult.

C. sappho Hall. One specimen, an adult.

Trigeria lefida Hall. Specimens few, but most of the growth stages are represented.

Eunella lincklæni Hall. Complete series.

Tropidoleptus carinatus (Conrad). Abundant both in young and mature stages.

Atrypa reticularis (Linnaeus). One specimen.

Cyrtina hamiltonensis Hall. Full series.

Spirifer mucronatus Conrad. Full series.

S. audaculus (Conrad). Some young specimens but not a full series.

S. granulosus (Conrad). Few specimens, all adults.

Delthyris consobrinus (d'Orbigny). Full series.

D. sculptilis Hall. Rare, all adults.

Reticularia fimbriata (Conrad). Rare, adults only.

Ambocælia umbonata (Conrad). A few very small specimens; adults not present.

Nucleospira concinna Hall. Rare, adults only.

Athyris spiriferoides (Eaton). Rare, adults only.

Pholidops oblates Hall. Common, full series.

P. hamiltoniae Hall. Abundant. Full series.

Crania crenistriata Hall. Rare. Incomplete series.

Craniella hamiltoniae Hall. Fairly complete series.

Stropheodonta concava Hall. Rare. Later neanic and adult stages only represented.

S. demissa (Conrad). Adults only, rare.

S. inaequistriata (Conrad). Common. Full series.

- S. junia* Hall. Rare, one adult only.
S. periplana (Conrad). Common. Full series.
Pholidostrophia iowdensis (Owen). Full series.
Orthothetes chemungensis (Conrad). Common, full series.
O. chemungensis arctistriatus Hall. Full series.
O. bellulus Clarke. Full series.
Chonetes coronatus (Conrad). Full series.
Chonetes mucronatus Hall. Full series.
C. scitulus Hall. Full series.
C. robustus Raymond. Full series.
Strophalosia truncata (Hall). Full series.
Productella spinulicosta Hall. Rare, all adults.
Rhipidomella penelope Hall. Rare, adults only.
R. vanuxemi Hall. Common, full series.

Craniella hamiltoniæ Hall.

Hall, Pal. N. Y., IV, 1867, p. 27, pl. 3, figs. 17-23.

Crania crenistriata Hall.

Hall, Pal. N. Y., IV, 1867, p. 28, pl. 3, figs. 13-16.

There are, among the shells from Canandaigua Lake, about forty dorsal valves of *Craniella hamiltoniæ*, the smallest of which is 3 mm. long and 3.6 mm. wide. The largest is 15.2 mm. \times 19 mm. One specimen retains both valves, and there is a single imperfect ventral valve attached to a specimen of *Tropidoleptus*.

Nearly half of the specimens show by their strongly corrugated surfaces that they were attached during life to a *Tropidoleptus*, while others show a variety of finer markings, or are entirely smooth. The young shells are, as a rule, more conical than the adults. The smallest shell has a height of 1.66 mm. or .55 of its length. Another, 5 mm. long, has a height index of .63. A specimen 6 mm. long has .52 for this index; one 7.5 mm. long has .35; one 11 mm. in length has .27 and the largest individual has .26. A few of the small ones are, however, quite depressed convex. One specimen, 4.16 mm. long has a height index of only .32, while, on the other hand, the index of a specimen 12.33 mm. long is .44.

The muscle scars show well in the dorsal valve, but add nothing to what is known of them. A specimen 3.6 mm. long and 3.86 mm. wide has the scars in the same relative position as in the adult, show-

ing that a constant and uniform migration of the posterior pair of muscles must take place. One specimen shows a sort of cardinal area on the posterior margin, which is, in this individual, nearly straight.

There is an incomplete series of nine dorsal valves of *Crania crenistriata*. They range in size from 2.66×3.33 mm. to 12.5×13.5 mm. It shows nothing of interest beyond the fact that there is a non-plicate nepionic stage, whose shell measures 1.46 mm. in length and 1.66 mm. in width, on the smallest specimen. There are 25 striae on this individual, all of which begin at the same time at the boundary of the nepionic shell.

Pholidops hamiltoniae Hall. (Plate I.)

Hall, Pal. N. Y., IV, 1867, p. 32, pl. 3, figs. 6-9.

There are, in the collections, about 1,500 specimens of this species, all but two of them separate valves. Next to *Chonetes scitulus*, this is the most abundant species in the material. The smallest specimen is .54 mm. in length and .46 mm. in width; the largest is 3.93 mm. long and 3.20 mm. in width.

Nepionic Shell.—On the beaks of the dorsal valves of some of the specimens the nepionic shells are preserved. At this stage the shell is wider than long, oval, and with a hinge line only slightly curved. The shell is convex and smooth. The largest shell of this stage seen is .15 mm. long and .176 mm. wide. The smallest is .13 \times .15 mm.

Changes During Development.

After the nepionic stage, growth of the shell takes place posterior as well as anterior to the beak. The shell becomes attached to some foreign object by the cementation of the ventral umbo. The amount of surface involved in this attachment is extremely small, so the symmetrical development of the shell is in no way prevented. On one specimen the scar is roughly oval, .13 mm. long and .11 mm. wide, and this is about the average size.

The first change, in outline, from the transversely oval shell of the nepionic stage is when the shell becomes elongate oval in the early neanic stages. At a length of .50 to .75 mm. it assumes the form which it retains throughout life. The beak is situated about one quarter (.21 to .28) of the length of the shell from the posterior margin, and the shell is broadest at the point.

The index of the nepionic shell is about 1.10 to 1.15; of the neanic .79 to .95, and of the adult .76 to .90. The average for ten specimens in neanic stages is .86, and of a similar number of adults, .83.

The shell substance is impunctate.

Muscle Scars. — The muscular area is roughly shield-shaped with the broad end directed backward. The front end is about the middle of the valve. The area is very small, as compared with the size of the valves. In a specimen 3.93 mm. long and 3.20 mm. wide the muscular area is 1.06 mm. long and .86 mm. wide. In a smaller specimen, 1.5×1.3 mm., the area is $.5 \times .5$ mm.

In both valves there are narrow transverse scars on the anterior and posterior borders of the area. In the ventral valve, behind the anterior transverse scar, are two large oval adductors. Their anterior ends nearly meet, and the posterior ends are widely separated. Back of them, at the corners of the shield, are two small round scars, and there is a double scar on the median line.

In the dorsal valve the anterior adductor scars are narrow and parallel. Behind them are two smaller scars and between them a median scar.

Pholidops oblata Hall. (Plate II.)

Hall, Pal. N. Y., IV., 1867, p. 414, pl. 3, fig. 10.

Of this species there are about 200 specimens in the collection. The smallest is 1.23 mm. long and 1 mm. wide. The largest is 7.8 mm. long and 7 mm. wide. A specimen of this species described by Hall is about twice the size of the largest shell in our collection. It is 15.5 mm. long and 14 mm. wide.

Nepionic Shell. — As in *P. hamiltoniae* the nepionic shell is oval, broader than long, convex, and with a slightly curved hinge line. The dimensions of the smallest shell of this stage are $.18 \times .20$ mm.; of the largest $.25 \times .27$ mm. (Fig. 1).

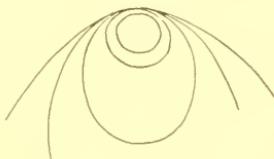


FIG. 1. *Pholidops oblata* Hall. Nepionic and early neanic stages, drawn from a dorsal beak. They might be termed the *Crania* and *Pholidops hamiltoniae* stages. $\times 30$.

Changes During Development.

After the nepionic stage the growth is more rapid in front than at the sides and an elongate oval form is produced when the shell is about .6 mm. long. The beak is then marginal and the greatest

width is about midway between the anterior and posterior margins. In older shells the interior retains this oval form, while the beaks of both valves project posteriorly, giving the exterior of the shell a roughly triangular appearance. The ventral beak is often more extended than that of the dorsal valve.

The index of the neanic shell is from 1.08 to 1.16. Of the neanic shells, from .96 to .65. Among the adults there are both wide and narrow forms. In the narrow ones, as seen from the inside, the periphery is elongate oval, while in the wide forms, it is circular. In general the index rises as the length increases, coming up from .76 in a shell 2 mm. long to .90 in one 7.8 mm. long. In no stage is there any evidence of a pedicle opening.

Muscle Scars. — The muscular areas are shield shaped, with the points directed forwards. The broad posterior side is close to the posterior margins of the shell, and the anterior point reaches about midway to the front.



FIG. 2. *Pholideops oblates* Hall. Ventral valve, showing anterior and posterior unpaired scars, anterior and posterior paired scars, and median scar. $\times 4$.

FIG. 3. The same species. Dorsal valve, showing the corresponding muscles. $\times 4$.

Both figures from specimens in the writer's collection.

FIG. 4. *Trematis millepunctata* Hall. Interior of dorsal valve after Hall and Clarke for comparison with Fig. 3. Copied from Fig. 4. Pl. IV G, Pal. N. Y., Vol. 8, pt. 1.

In the ventral valve, there is a narrow transverse scar forming the front of the shield. In some specimens this seems to be made up of two scars, one on either side of the median line of the shell. Behind this are two large oval scars, situated obliquely, with their anterior ends nearly, but not quite, meeting. Behind these, at the posterior corners of the shield, are two smaller scars which are roughly triangular in some specimens and nearly round in others. Between these is an elongate scar, divided into two parts along the median line. On

the posterior end of the shield is a narrow, crescent-shaped, transverse scar (Fig. 2).

In the dorsal valve the arrangement is much the same, except that the anterior pair of scars, instead of being oval and oblique, are elongate and run back to the posterior transverse scar. The scars of the posterior pair are situated outside of the narrow part of the anterior scars, and are slightly smaller than the corresponding scars in the opposite valve (Fig. 3).

The main scars probably are analogous to the anterior and posterior occulators of *Crania*, and the posterior scar may have the same functions as the umbonal scar in *Lingula*. A very similar arrangement of scars is seen in *Trematis* (Fig. 4).

Stropheodonta inaequistriata Conrad. (Plate III, Rows 3, 4, 5.)

Conrad, Pal. N. Y., 1867, p. 93, pl. 12, figs. 6-8.

In the Canandaigua Lake material there are about four hundred well preserved pedicle valves, and about one-half as many dorsal valves of this species. The dorsal valves are not so well preserved as the ventral valves, as the anterior part is usually broken away. Only about twenty specimens which retain both valves were obtained, and these were nearly all adults.

The smallest specimen in the collection is 1.2 mm. long and 2.2 mm. wide. The largest is 16 mm. long and 27 mm. wide. All gradations between the two are shown. Hall (Pal. N. Y., Vol. IV, plates 15 and 18) figures several specimens, all adult or senile individuals from the Corniferous and Hamilton. The smallest is 12 \times 18 mm. and the largest 22 \times 29 mm. The specimen figured on Plate 18, fig. 2k, Pal. N. Y., Vol. 4, shows the muscle scars in the ventral valve of a senile individual, and fig. 10, pl. 15, shows the muscle scars of the adult. Fig. 11 on the same plate shows well the interior of the dorsal valve, with the adductor scars (which are not represented as divided into two pairs) and the strongly raised curved ridges in front of the scars of the senile individual. Fig. 2h, pl. 18, shows the muscle scars and ridges of a younger specimen, probably in the early ephebic stage. The species is placed by Hall and Clarke with *S. arcuata* Hall, *S. cayuta* Hall and *S. variabilis* Calvin, in the division Douvillina of Ehlert.

Nepionic Stage.—In the nepionic stage the shell is oval in outline and wider than long. Both valves are convex, though the dorsal valve becomes flat in front in some specimens. In the dorsal valve

there is a narrow fold which extends about half way to the front. Otherwise the shell is smooth. The width at the hinge is a little less than the width below. The length of an average specimen is .42 mm. and the width .54 mm.

Changes During Development.

Outline. — Immediately after the neionic stage the width at the hinge becomes greater than the width below and remains so throughout all succeeding stages. The cardinal extremities are most alate during the adolescent period and all immature forms are characterized, when perfect, by very long hinge lines. In the senile state, the cardinal angles are rounded a little, but the width at the hinge is still greater than the width below. From the early neanic through the adult stages the index increases gradually, while in senile specimens the anterior growth lowers it again. It varies from 1.25 to 1.50 in adolescent individuals and from 1.50 to 1.75 in adults. In one senile specimen it falls as low as 1.19.

Convexity of Valves. — In the neionic stage both valves are convex, but when a length of about .50 mm. is reached, the dorsal valve becomes concave in front and follows very closely the contour of the other valve throughout the succeeding stages. Shells from 1 to 6 mm. long are very slightly convex, sometimes almost flat, but as they grow older, the convexity increases, until, in the gerontic stage, they are almost hemispherical.

Striae. — The smallest specimen showing striae is 1.1 mm. long and 1.8 mm. wide. It is a ventral valve and has nine strong striae, be-

tween which are extremely fine striae which can hardly be made out. Five of the prominent striae extend back to the line bounding the neionic shell. One of these is on the median line of the valve and has a pair on either side of it. Between each pair of these striae a striation is implanted near the anterior margin of the shell (Fig. 5).

After this stage the number of striae increases rapidly, by implantation. An adult has from 30 to 60 prominent striae with bundles of three to five smaller striae between them. They are not obliterated in the senile stages, but increase in number with the increase of the shell in size. There are, in that stage, from 50 to 80 of the strong striae.



FIG. 5. *Strophedonta inequistrata* (Conrad).

Ventral valve, showing the primary striae. $\times 8$.

Muscle Scars. — In young stages the muscle scars are so faint that they are almost indistinguishable. The smallest ventral valve, in which anything definite can be made out, is 4×4 mm. In it the diductors have oval, somewhat widely separated, scars, between which are the two small adductors, one on either side of the median line. The diductors are bounded posteriorly by two ridges which make a wide angle with each other. The adductor scars have faint ridges on either side and another ridge between them. In a little later stage these three ridges around the adductors become sharp and distinct. The median one runs back nearly to the beak, while the outer ones remain short, sharp and rather high, curving outward. In the later neanic stages these ridges arch over and join the ridges which bound the diductors (Fig. 6). The two ridges which bound the posterior

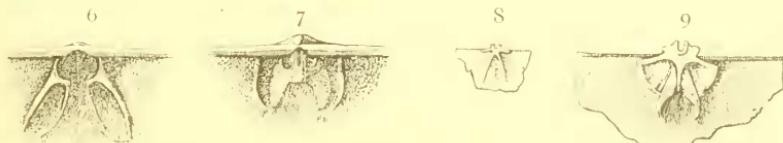


FIG. 6. *Strophodonta inaequistrigata* (Conrad). Ventral muscle area and ridges of an individual in later neanic or ephobic stages. $\times 2$.

FIG. 7. The same species. The corresponding area in ventral valve of a specimen in later ephobic or gerontic stages. $\times 2$.

FIG. 8. The same species. Interior of the dorsal valve of a young specimen, showing cardinal process and ridges in front of it. $\times 2$.

FIG. 9. The same species. Interior of the dorsal valve of an adult, showing the two pairs of adductor muscle scars and the brachial ridges in front of them. $\times 2$.

Figs. 6-9 are from specimens in the writer's collection.

borders of the diductor impressions send off processes a short distance in front of the hinge which turn inward and run parallel for a short distance. They rise sharply from the floor of the valve and overhang on the side toward the median line. In the later neanic stages the whole extent of the diductor impressions is bordered by a long sharp ridge which is later resorbed.

During the adult stage, the parallel portions of the two ridges which bound the diductors are extended and strengthened, and the divergent portion is resorbed. The median ridge becomes stronger and rounded, the two sharp ridges which separated the adductors from the diductors disappear, and an almost square muscle scar is produced. In this scar the diductors are very plain, and the adductors are narrow and situated somewhat posteriorly. Behind these is a median pedicle muscle (Fig. 7).

In the brachial valve of some specimens the adductor muscle scars are well defined and in others they are very faint. They are usually bounded by a low ridge. The outer pair, the posterior adductors, make up most of the scar. They are small, roughly triangular, and situated close to the front of the cardinal process. The anteriors are narrow, and are situated on a platform between and slightly above the level of the posteriors (Fig. 9).

Between the scars, on the median line, is a low, short septum which is hardly elevated above the surface of the shell in young specimens but becomes prominent in adults. On either side of it is a low ridge which extends back nearly to the base of the cardinal process. In the adult the portion of the ridges in front of the muscle scars becomes high and incurved, and may function as a support for the brachia. These ridges are short, and their anterior ends are not half way to the front of the valve (Figs. 8 and 9).

They appear to be homologous with similar ridges in *Chonetes scitulus*, which certainly are connected with the brachia. The structure of the muscle scars and ridges in this species should be compared with that of the dorsal valve of *S. concava* (Fig. 16).

Hinge Structure. — The young specimens do not preserve the hinge structure, but in adult and senile stages, the deltidium is present and covers the delthyrium entirely. The pedicle opening is forced back into the beak. In a specimen 7 mm. long and 11.8 mm. wide the deltidium is continued into a short, exsert pedicle tube. The aperture at the apex of this tube is about .05 mm. in diameter, which is fully twice the diameter in some of the adult and gerontic specimens examined.

Crenulations. — In the smallest specimen (3 mm. wide) which showed any trace of crenulations, .66 mm. on each side of the middle point of the area was marked by faint depressions, about 6 on each side. Thus about .44 of the area was crenulated. A specimen 4.7 mm. wide had .43 of its hinge width crenulated. A specimen 6 mm. wide has .66 of its width crenulated. Another specimen, 12 mm. wide, had .71 of its width crenulated. A specimen 2.4 mm. on the hinge line, had crenulations which extended .56 of the distance between the cardinal extremities. A senile individual had crenulations covering .57 of the hinge width. Thus it is seen that a greater proportion of the hinge is crenulated during the later neanic and adult stages than during the early adolescent or senile periods.

Cardinal Process. — The cardinal process is deeply bifurcate in the youngest specimens showing it. In older stages each part is again divided by a sharp depression which becomes deeper as development goes on. On each side of the process are the dental lamellæ, which, in young specimens, are sharp and thin, but later become low and rounded. In some adults they are hardly to be distinguished from the two ridges which bound the posterior adductor scars.

The Same Species From Other Localities.

A single specimen from Genessee, N. Y., is smaller than the ones just described. It is 16×19 mm. and has 26 prominent striae, between which are fascicles of seven or eight small ones. This specimen is quite regularly convex.

There are several specimens from East Bethany in the collection, all of which are small, but show mature characters. The largest specimen is 16×21 mm., and has 60 prominent striae in front with groups of three or four smaller ones between. The smallest is 8×11.5 mm. and has 23 striae on the front. An average specimen is 13×20 mm., with 50 prominent striae on the front, 9 of which extend to the beak. Although the specimens are small they are strongly convex, instead of being moderately convex or nearly flat, as is the immature condition of the specimens from Canandaigua Lake.

Stropheodonta perplana Conrad. (Plate III, Row 1.)

Hall, Pal. N. Y., 1867, pp. 92, 98, pl. 11, fig. 22, pl. 12, figs. 13-15.

There are, in the collection, about 150 nearly perfect specimens belonging to this species. The majority of them are separate valves, more of the ventral than of the dorsal, and, as is the case with *S. inaequistriata*, the pedicle valve is the more perfectly preserved. A few adult individuals retain both valves. The specimens range in size from 1.6×1.8 mm. to 21×24 mm. All stages between these limits are represented. On the beaks of both valves the younger stages are well shown.

A figure showing the deltidium, pedicle opening, and nepionic stage of this species has been published by Beecher (Am. Jour. Sci., 3d series, Vol. XLI, 1891, p. 357, pl. 17, fig. 17). Hall has figured specimens from the Corniferous, Hamilton and Chemung. Of these, the smallest from the Corniferous is 15×19 mm., the largest 37×46 mm. The smallest from the Hamilton is 19×20.5 mm. and the

largest 38×49 mm. From the Chemung the smallest specimen figured measures 33×39 mm., and the largest 42×61 mm.

Protegulum. — The protegulum is nearly circular, both valves convex, and with arcuate hinge. It measures $.10 \times .10$ mm. in one specimen and $.12 \times .12$ mm. in another.

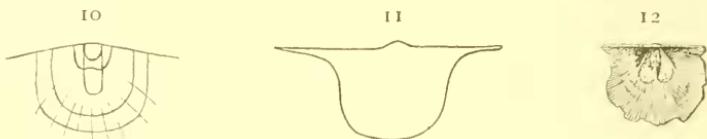


FIG. 10. *Strophodonta perplana* Conrad. Dorsal valve, showing shell in neanic stage, the fold, and the origin of the striae. $\times 16$.

FIG. 11. The same species. Outline of the ventral valve, showing the acuminate cardinal extremities. $\times 3$.

FIG. 12. The same species. Interior of ventral valve, to show the diductors and the two pairs of adductor scars. $\times 1$. Compare with Figs. 14 and 17. The specimens are in the writer's collection, now deposited in the Carnegie Museum.

Nepionic Stage. — The shell, in the neanic stage, is convex in both valves, nearly as long as wide, and with a hinge width about as great as the width below. In the dorsal valve there is a fold which extends nearly to the front of the shell. Otherwise the valves are smooth. The dimensions at this stage are: in one shell, .56 mm. long and .64 mm. wide; in another, $.60 \times .72$ mm. (Fig. 10).

Changes During Development.

Outline. — In early neanic stages, the width of the hinge becomes greater than the width below, and, during all the adolescent period, the shells are strongly alate and the hinge width is frequently two and a half or three times the length of the shell (Fig. 11). In the adult stages the hinge width is still the greatest width of the shell, but the cardinal extremities are not far extended. In one young individual, with a width of 7 mm. on the hinge line, each extremity forms a spinelike extension 1.5 mm. long, thus making up nearly one half the total width. Other specimens 10 mm. wide at the hinge, have alate extremities, each 2 mm. in length. In computing the index, the width below the hinge was taken and it was found that, apart from the extensions of the cardinal angles, there is very little change in form through life. The older shells are a little longer, in proportion to the width, than the young ones. The index, in neanic stages, is about 1.45 to 1.50 mm. and, in the adult, 1.35 to 1.20 mm.

Convexity of Valves. — Immediately at the end of the neionic stage the dorsal valve becomes slightly concave, and remains concave or flat throughout the remaining stages of its development. The pedicle valve is convex in all stages, but never strongly so, producing a nearly flat shell.

Striae — Just at the anterior edge of the smooth neionic shell the striae begin. They are introduced in pairs on the dorsal valve while the pedicle valve has an unpaired median stria. A shell .75 mm. long and 1 mm. in width has seven striae on the ventral valve and eight on the dorsal. Before the shell is 1 mm. in length the older, that is, the middle striae, have bifurcated, and, from that time, the increase of striae is rapid and new ones are added by both bifurcations and implantation. A shell 1.8 mm. long has 19 striae. One 2.8 mm. long has 45, one 8 mm. in length has 140, and one 16 mm. long has 200. In neanic stages the extended cardinal angles are smooth, even after the striae become numerous in front. In adult shells, the striae cover almost the entire surface. Very fine concentric lines cross the striae. Near the umbo and occasionally all over the shell, are faint concentric undulations. They are especially strong in young shells and dorsal valves.

Crenulations. — On the smallest shell, in which the hinge is preserved 2×2.5 mm., the crenulations extend .6 of the distance from the beak to the cardinal extremity (not an alate shell). On a larger shell, 5.3 mm. wide at the hinge, .8 of the distance is crenulated, and in all individuals larger than that, the crenulations extended the whole width of the shell.

Pedicle Opening. — The material does not illustrate this part of the development well. No very young specimens retaining both valves were found, and the young ventral valves are all broken at the beak. An adolescent individual, 5.6×8.4 mm. shows a flat deltidium, whose limits can hardly be distinguished, and a relatively large pedicle opening just behind the beak. In adult specimens there is a more or less convex deltidium, often not well defined at the sides, and the pedicle opening is very small and pushed forward on to the beak.

Muscle Scars. — The muscle scars of young specimens are not strongly marked in either valve. In the ventral valve of the adult, the diductors leave elongate, flabelliform scars. Between them, lying on either side of the low median septum, are the two long oval scars of the adductors. Diagonal lines divide each scar, marking the limits of the anterior and posterior elements (Fig. 12).

The diductors are bounded behind, and at the sides by two low, pustulose ridges, and the whole interior of the valves outside the scars, is covered with smaller pustules.

In the dorsal valve there are two pairs of adductor scars bounded posteriorly and laterally by ridges, but not well limited in front. The anteriors are situated between the posteriors and are divided from them by faint ridges.

There is, as far as could be seen, very little change in these scars from the young through the adult stages. In the dorsal valve, the ridges, which limit the posterior and lateral sides of the scars, are more divergent in young stages than in the adult, thus producing relatively narrower scars in the adult than in the neanic specimens.

Unfortunately no specimens showing strong gerontic characters have been obtained from this material.

Pholidostrophia iowaensis Owen.

Hall, Pal. N. Y., IV, 1867, p. 104, pl. 18, fig. 1.

In the collection there are about 130 specimens, ranging in size from 1.6×2 mm. to 14×16 mm. Three specimens retain both valves in their proper relations, but the remainder are separate valves. The specimens figured by Hall are adult and gerontic individuals. The smallest is 11.4×14 mm. and the largest 13×17 mm.

Description of Smallest Shell. — The smallest shell in the collection is 1.6×2 mm., semi-elliptical in form, with a width at the hinge greater than the width below. The ventral valve is gently and regularly convex, while the dorsal valve is convex at the beak and concave, nearly flat in front. The surface is smooth on both valves.

Changes During Development.

Outline. — During the neanic stages the cardinal extremities are alate and the hinge width is usually one and one-half to twice the length of the shell. In adults the width at the hinge equals or is a little less than the width below, and the length and width frequently become very nearly equal. The young shells are not, however, so strongly alate as the young of *Strophodonta perplana*, but this is largely due to the accidental removal of the tips of the cardinal extremities. One specimen, a ventral valve, shows three stages of growth, and the spiniform extremities of each are fairly well preserved. Instead of the new growth being added to the whole length of the hinge, these ex-

tremities have been left free so that the first two pairs form spine-like processes, raised slightly above the surface of the shell. The shell, up to the first distinct growth line, has a length of 2.5 mm. and a width of 5 mm. The spines are each 8 mm. long. The second stage is 3×8.6 mm. and each spine is 2.5 mm. long. The shell at the last stage is 6×10 mm. and the spines 2 mm. long. So, if the spiniform extensions were preserved in ordinary specimens, the outline would be very different from that usually seen in this species (Fig. 13).

The index, disregarding the alate cardinal extremities, falls from early neanic to senile stages, the length becoming constantly greater, in relation to the width. The extremes are 1.50 and 1.00 mm. but the average, in neanic specimens is from 1.30 to 1.45 mm. and, in adult and senile individuals from 1.10 to 1.25 mm.

Convexity of Valves. — In all stages, up to the later adult and gerontic, the ventral valve is gently and regularly convex, and the dorsal valve flat or slightly concave. Late in the development, the shells become rather abruptly and strongly deflected in front, which makes the ventral valve very convex in this part and the dorsal valve correspondingly concave. The exterior of the shell remains smooth in all stages except for the strong growth varices, of which there are usually at least two or three, and, in gerontic individuals several, toward the front.

Crenulations on the Hinge. — On a specimen 2×3 mm. the crenulations occupy less than half (.45) of the length of the hinge. Those under that size do not seem to have any crenulations. A larger specimen, 5.6×7.3 mm., has crenulations which occupy a little more than half (.59). In adults the crenulations cover about this same amount. In one specimen it was .58, and in another .64, which was the highest observed.

Pedicle Opening. — In the adult, the pedicle opening is very minute and encroaches upon the beak. The deltidium is perfectly flat and the longitudinal striations on the cardinal area extend across without any break. Occasionally the outline of the deltidium is fairly well marked. In young specimens there is a pedicle tube which projects a little beyond the beak.

Muscle Scars.

Pedicle Valve. — There are two large flabelliform diductor scars and, between them, posteriorly, are the two elongate oval ones of the adductors, one on each side of the low median septum. Each scar is

divided by a diagonal line, into anterior and posterior parts (Fig. 14).

In the dorsal valve are two pairs of adductor scars. On each side of a low rounded median septum is a small oval anterior adductor scar. At the sides and a little posterior are the larger posterior pair. These scars are surrounded by low ridges which are more strongly developed at the back and sides than in front (Fig. 15).

The median septum in this valve is produced for some distance in front of the muscle scars and in the adult and senile specimens is rather high and strong. Beginning just in front of the middle of the

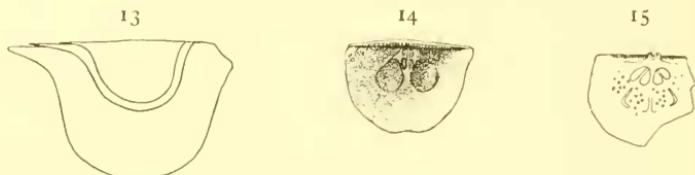


FIG. 13. *Pholidostrophia iowaensis* (Owen), ventral valve showing the acuminate cardinal extremities of young specimens. $\times 3$

FIG. 14. The same species. Interior of ventral valve, to show the adductor and diductor muscle scars. Natural size.

FIG. 15. Interior of dorsal valve of the same species showing the adductor muscles scars and the ridges connected with the brachial impressions. Natural size.

FIG. 13. From a specimen in the Yale University Museum collection. Figs. 14 and 15 from specimens in the writer's collection.

scars, on each side of the septum is a low ridge which curves gently outward and then inward again, turning in rather abruptly as a sort of hook at the anterior end (Fig. 15).

In adults these processes extend about two thirds of the distance to the front of the shell. In the young, they extend somewhat further forward and are more divergent. These ridges correspond, in position, with the brachial ridges of *Chonetes*, *Productus*, etc., and should probably be correlated with those markings.¹

The genus *Pholidostrophia* was suggested by Hall and Clarke to include a section of *Stropheodonta* in which the shells were concavo-con-

¹ Ridges much like these, in *Stropheodonta leblanci* Rouault were described by Ehlers as belonging to the brachial apparatus. In describing the interior of the dorsal valve of that species he says, "Les empreintes des muscles adducteurs . . . sont très rapprochés de la ligne cardinale et occupent de chaque côté du septum une surface fortement bilobée; entre chacun de ces lobes prennent naissance deux petits bourrelets saillants, recourbés en hameçon, qui sont connus, dans la famille des Productidæ, sous le nom d'empreintes reniformes, et qui doivent appartenir à l'appareil brachial." Annales des Sciences, Géologie, Vol. XIX, p. 63, pl. IV, fig. 10.

vex, had no striae, and were strongly punctate. The interior of the brachial valve was characterized as bearing three divergent ridges in front of the muscular area.

Stropheodonta nacrea Hall, from the Corniferous and Hamilton, an unnamed species from the Corniferous, and *Strophomena lepis* Brönn. of the Middle Devonian from Eifel, Belgium, and the Asturias, were named as belonging to this division.

It has been shown that the development of the hinge structure, form of shell, and convexity of valves is very similar in the three species just described. The points of greatest difference were: first, in the striae—*S. inequistriata* produced new striae by implantation; *S. perplana* by both implantation and bifurcation; and *P. iowensis* has normally no striae at any stage of development; second, in the scars of the muscles—*S. inequistriata* has a type very different from that of the other two, and, in the ventral valve, there is a change in the form of the muscles during the ephebic and gerontic stages. In the other two species no such change has been observed to occur.

Comparing the scars in the ventral valves of *S. junia*, *perplana*, *demissa* and *P. iowensis*, it is at once seen that they are very similar. In each, the diductors are broad, flabelliform, separated by a low septum and bounded on their posterior-lateral edges by more or less papillose ridges. In *S. demissa* and *P. iowensis*, they are more sharply marked in front than they are in the other two species. Between the diductors are the elongate scars of the adductors, two pairs in each case. In the dorsal valves of *S. demissa*, *S. perplana* and *P. iowensis*, there is more variation in the form of the scars, but it is more a variation in the limiting structures than in the shape of the scars themselves. In each, there are two pairs of scars, one pair somewhat anterior to, and between the other pair. In *S. demissa* and *P. iowensis* they are bounded by a ridge in front. In *S. perplana*, the anterior margin is more indefinite. The interior of the dorsal valve of *P. iowensis* should be compared with that of *Stropheodonta profundu* Hall from the Niagara (Pal. N. Y., Vol. VIII, I, pl. 20, fig. 30). In that species the form of the scars is almost exactly the same as in the Hamilton species, and in front of the scars there are two short, curved ridges and a prolongation of the median septum. Hall thus describes this species. "Shell large, full grown individuals having a width of 60 mm. and length of 40 mm. deeply concavo-convex. Ventral valve very convex, hinge line narrow, foramen triangular,

covered by a strong deltidial callosity. Crenulations on the interior margin are oblique, diverging from the beak, extending from the foramen less than half way to the cardinal angles. Surface marked by strong, large radiating striae alternating with four or five smaller striae and increasing by implantation" (Eleventh Annual Report Indiana State Geological Survey, 1881, p. 289). Here then there are examples of four of Hall and Clarke's subdivisions; *Brachyptrion*, *Leptostrophia*, *Pholidostrophia*, and *Stropheodonta* (*S. demissa* type) which agree in internal structure but have great variation in external ornamentation. These facts would seem to indicate that the name *Pholidostrophia* should be given the same taxonomic value as the names *Brachytioptrion* and *Leptostrophia*, instead of being raised to generic rank.

The Same Species from Other Localities.

Specimens from East Bethany, N. Y., are of about the same size as the Canandaigua Lake specimens, but are somewhat wider in proportion to the length. The index is from 1.39 to 1.49 mm.

From Eighteen Mile Creek there are numerous specimens, most of which are smaller than the largest ones in the present collection. The smallest is 8×10 mm. and the largest 12×17 mm. An average specimen is 10.5×14 mm. Most of the specimens have their cardinal extremities more or less extended. One specimen that is 14 mm. wide below the hinge, measures 18.5 mm. along the hinge. Another 14 mm. in width below, is 17 mm. on the hinge. These specimens are only moderately convex and have not yet reached the stage when they are sharply deflected in front. One of the specimens shows indistinctly a few distant, radiating striae.

Very similar to these, but with a slightly lower index, are the specimens from Thedford, Ontario. These specimens are very uniform in size. The largest is 11.5×15 mm. and the smallest 10×13.5 mm. The index is 1.30 to 1.35 mm.

NOTES ON OTHER SPECIES OF STROPHEODONTA.

S. concava Hall.

Hall, Pal. N. Y., IV, 1867, p. 96, pl. 16, figs. 12 and 15.

One well preserved dorsal valve shows the character of the muscle scars in this species. The adductor scars are large, broadly oval, and separated by a median depression in place of the usual septum. The

scars are divided into two elements, the posterior adductors, which are large and oval, and in front of and between these, the small triangular anteriors. In front of the muscle scars there is a median septum and on each side of it a rounded postulose ridge. Outside these ridges are two lower, sharper ridges one of which starts in front of each anterior muscle scar, curves slightly outward, and then in again, but does not approach much nearer the septum than it was at the starting point. These ridges probably have to do with the brachial apparatus rather than with the muscular system, as has been previously supposed.

S. junia Hall.

Hall, Pal. N. Y., IV, 1867, p. 108, pl. 18, figs. 3, 4.

Only one well preserved specimen of this species was found in the collection. It is a ventral valve, 44 mm. in length and 50 mm. wide. The hinge is crenulated for three-fifths of the distance from the beak to the cardinal extremities. The area about the beak is broken, so nothing could

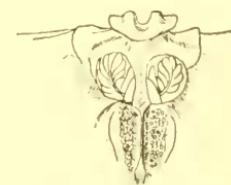
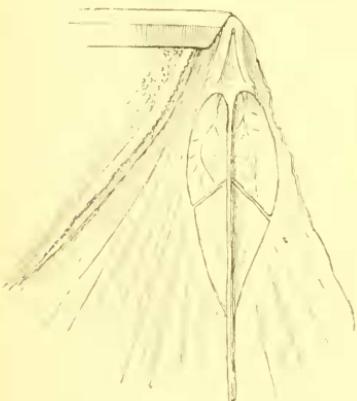


FIG. 16. *Stropheodonta concava* Hall. Sketch of the cardinal process and muscle area to show the two pairs of adductor scars (the small triangles without arborescent markings represent the anteriors) the low median septum ending in a sort of saddle, and the postulose ridges, not muscle scars, on either side of it. Natural size.

be learned about the deltium or pedicle opening. The scars of the muscles are very well marked. The diductors are large, flabelliform, faintly marked anteriorly, but with strong posterior ridges extending from the area half way down the sides. Between the diductors are the adductor impressions which are divided on the median line by a low, thin septum. These scars are long, narrow and acuminate in front. Two diagonal lines divide the scars into anterior and posterior elements and the posteriors have arborescent markings, while the anteriors, which are smaller, do not. Back of these remnants of the dental plates, and

FIG. 17. *Stropheodonta junia* Hall; part of the muscle area of a ventral valve, showing the anterior and posterior elements of the adductors, and the pedicle muscle scar. $\times 3$.

scars are two low processes, the



on a platform made when they unite with the median septum is the scar of the pedicle muscle. The entire interior of the valve, outside the muscle scars, is covered with small pustules (Fig. 17).

S. demissa Hall.

Hall, Pal. N. Y., IV, 1867, p. 81, pl. 11, figs. 14-17, pl. 12, figs. 1-5.

This species is represented by two or three poorly preserved ventral valves. None are sufficiently complete to give measurements of length and width. The hinge structure is fairly well shown. The deltidium is broad and convex, and the pedicle opening is just at the beak. One specimen shows well the course of the pedicle. The rudimentary teeth are supported by a median septum formed by the coalescence of the two dental lamellæ. Between the teeth and running to the beak is a groove, covered over by the deltidium, thus forming a pedicle passage. The median support is very short and in front of it is the scar of the pedicle muscle.

The diductor scars are very large, flabelliform and bounded by two diverging ridges which are widely separated posteriorly. The adductors form a rather large oval scar which is divided longitudinally by a raised line. Toward the front of the scar are two faint diagonal lines which mark off the anterior adductors. They are very much smaller than the posterior pair and acuminate in front. The median septum is not strongly developed in front of these scars.

Orthotetes¹ chemungensis Conrad. (Plate V, Rows 1, 2.)

Hall, Pal. N. Y., IV, p. 67, pl. 10, fig. 6.

In this collection there are about four hundred specimens of *Orthotetes* representing all stages of growth from a size of $.71 \times .80$ mm. to 16×22 mm. Well preserved large specimens are uncommon and the majority of the individuals are less than 10 mm. in width. On the other hand, specimens less than 2 mm. in width are common. There are in this material two species, one of which, *O. chemungensis*, is represented by two varieties, *O. chemungensis arctistriatus* Hall and *O. chemungensis pectenacea* Hall. Most of the material can be

¹In a paper on "New Molluscan Genera from the Carboniferous" (Proceedings of the U. S. National Museum, Vol. XXVII, page 721, 1904) Dr. Girty states that *Orthotetes* (*sic*) as defined by Fisher-de-Waldheim covers the type of structure for which Waagen proposed the name *Derbyia*. Thus, according to Girty, *Derbyia* becomes a synonym for *Orthotetes*, and he suggests *Schuchertella*, for shells of the type of *Streptorhynchus lens* White.

referred to these two varieties, while the other species, *O. bellulus* Clarke, is represented by about 60 specimens. A number of the smaller individuals retain both valves, but most are separated and there are about as many of one valve as the other.

Hall, in 1867, referred all the specimens of this genus found in the Upper Helderberg, Hamilton, and Chemung, of New York, to the single species *Streptorhynchus chemungensis* and divided it into four varieties, *S. pandora* from the Schoharie and Corniferous, *S. arctostriata* from the Hamilton, *S. perversa*, Hamilton, and *S. pectenacea* for the Chemung. He stated, however, that there exist such gradations between these that it is extremely difficult to distinguish them and that specimens exactly like *S. pandora* are found in the Chemung, while the varieties *arctostriata* and *perversa* are not confined to the Hamilton. Schuchert, in 1897, divided the group by making two species and two varieties. *Orthothetes chemungensis*, including Hall's variety *pectenacea*, is restricted to the Chemung specimens. *O. chemungensis arctostriatus* to the Hamilton, *O. chemungensis perversus* to the Hamilton and Corniferous, and *O. pandora* Billings to the Upper Helderberg.

The differences between the varieties seem to have been based largely on surface ornamentation. From the descriptions given in Vol. IV, Pal. N. Y., the following principal characters are taken.

"Such forms as *S. arctostriata* have the striae nearly equal and quite thin and prominent, but even then there are fine intermediate striae, but the interspaces are so nearly equal that the surface presents a pretty uniform aspect, though there are many gradations. Specimens of this kind have usually very broad convex dorsal valves which are sometimes depressed in the center."

S. pectenacea.—"Surface marked by distant prominent striae with two or three finer ones between. Well marked specimens are usually small or medium size."

Numerous specimens of these varieties are figured. The majority of them are much larger than any in the present collection. Hall states that the usual size of *S. arctostriata* is from one-quarter to three-quarter inches in length and the width one-quarter to one-third greater. The smallest specimen figured is 7×13 mm. and the average is from 16×25 mm. to 25×40 mm. It will thus be seen that the material here described consists mainly of immature and dwarfed specimens.

Developmental Changes.

The two varieties have practically the same development, as the only difference is in the time of the appearance of the new striae. They will therefore be considered together. In the adult the two can be separated only under the most favorable circumstances. In well-preserved specimens the variety *arctistriatus* shows a surface thickly covered with sharp, subequal striae. *O. pectenacea* has slightly wider spaces between the striae and certain of the striae are stronger than others. With young specimens, especially if the dorsal valves are at hand, there is no difficulty in separating them. The variety *pectenacea* has from 15 to 19 strong elevated striae between which are lower interspaces containing one or three striae. In the variety *arctistriatus* the striae are so crowded together that this alternating appearance is not obtained.

Nepionic Stage. — The smallest shell in the collection is a dorsal valve .71 mm. in length and .80 mm. wide. It is almost circular in outline, slightly convex, and is smooth for half the distance to the front. There are fifteen sharp striae, all originating at the same time.

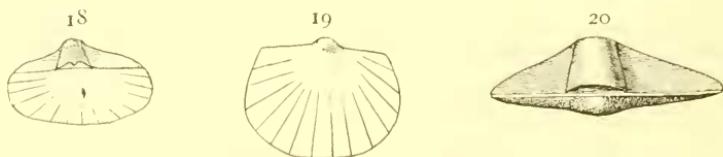


FIG. 18. *Orthothetes chemungensis* Conrad; specimen retaining both valves, and showing pedicle tube and primary plications. $\times 16$.

FIG. 19. Ventral view of the same specimen. $\times 16$.

FIG. 20. The same species. Cardinal view of another specimen showing pedicle tube and relative convexity of valves. $\times 32$.

The nepionic stage in this species is of short duration. On all the well preserved dorsal valves the smooth initial shell can be seen. It is almost exactly circular, convex, and from .35 to .43 mm. in diameter, usually about the lower limit.

The smallest ventral valve is on a specimen which retains both valves. It is .73 mm. long and 1.1 mm. wide with a width of 1 mm. at the hinge. It is subelliptical in outline, convex, with a high cardinal area. The delthyrium is almost completely closed by a strong convex deltidium, which at the apex is prolonged slightly, forming an exert tube which is perforated for the passage of the pedicle. On this specimen there are 13 striae on the dorsal, and 14 on the ventral valve (Figs. 18, 19).

Changes During Development.

Outline. — There is very little change in the outline except as it is affected by the irregular growth. In the neionic stage the shells are circular but become wider than long in the earliest neanic stage and remain so through all succeeding stages. The width at the hinge is always less than the width below. The index is from 1.25 to 1.50 mm. in neanic stages and 1.50 to 1.80 mm. in adult and gerontic stages.

Convexity of Valves. — The dorsal valves of young shells are nearly flat or slightly convex, but become more convex in the adult when the greatest convexity is about the middle of the valve. The ventral valve is always more convex than the opposite one and is often rather sharply deflected in front.



FIG. 21. *Orthothetes chemungensis arctistriatus* Hall. Diagram of a dorsal valve to show the 12 primary striae. Between two of them the secondary, tertiary and quaternary striae are filled in, to give an idea of the uniform appearance produced by the crowding of the striae. $\times \frac{3}{2}$.

FIG. 22. *O. chemungensis pectenacea* Hall. Dorsal valve, showing earlier plications. $\times 12$.

Striae. — The shell of the variety *pectenacea* has, up to a length of 1 to 1.2 mm., 13 to 15 simple, sharp striae separated by spaces which are wider than the striae. Then there appear four or six new striae in the middle of the front, implanted, one in each interspace (Fig. 22). Later more are added until there is one between each pair of the original striae. The next step is the appearance of striae, again in pairs, one implanted on each side of each of the secondary striae. At a still later stage more pairs are added, one on each side of the next previous ones to appear. So in the adult we have, considering a single unit of striae, first, two striae extending from the anterior margin to the smooth portion of the shell at the beak; second, a single striation bisecting the area between the first two but not extending to the beak; third, a pair, one on each side of the bisecting striations but not more than half as long; and fourth, four more striae, one in each of the spaces between the preceding ones. These last ones are usually

very short. Thus there are seven striae between each pair of the original simple striae, and theoretically, 113 striae on the adult of an individual which, in the initial plicated stage, had 15. Very frequently, however, some of the striae are suppressed, and this is almost always the case at the sides. In the larger specimens, more striae are probably added in this same way (Fig. 23).

In the other variety, *arctistriatus*, the method of development is the same, but the result is somewhat different. In the earliest striated stage there are from 15 to 19 sharp striae. New striae appear as before,

but come in at earlier stages, thus covering the surface of the valve more completely, and giving a more uniform appearance to the striae (Diagram, Fig. 23).

Cardinal Area.—The height of the cardinal area varies greatly with the individual specimens. Series can be selected in which the ventral valves are subpyramidal while others have so low or curved an area that the valves are almost uniformly convex. One specimen, with a hinge width of 1 mm., has an area .36 mm. in height. One 5 mm. wide, at the hinge, has an area of 2 mm. in width. An adult, 16 mm. on the hinge line, has an area 8.3 mm. high. Another with a hinge

FIG. 23. Diagram showing the method of inception of plications in the two varieties of *Orthothetes chemungensis*. The seven lines in the middle represent the seven striae as developed between two primary striae in the variety *pectenacea*, and the other lines represent the groups of striae in the variety *arctistriatus*. Notice that No. 4 comes in later in the middle group than in the outer ones, 2 and 6 later in the middle than 2 and 6 in the outer ones, etc.

width of 22 mm., has an area only 4 mm. high.

The area is divided by two oblique lines extending from the beak to the hinge. These lines, with the boundaries of the deltidium, form two scalene triangles, one on each side of the delthyrium. The area within these triangles is somewhat different from the rest of the cardinal area. It is striated vertically as well as horizontally, and, in some specimens where the rest of the area is punctate, this part is not so. The youngest specimens show no trace of these triangles but a specimen 3.6 mm. in width at the hinge shows the distal ends of the oblique lines 1 mm. from the extremities and the other ends close under the beak. In a specimen 5 mm. in width the triangles occupy a

slightly greater proportion of the area and their acute angles are only .75 mm. from the cardinal extremities. About the same proportion is maintained through all the succeeding stages. A specimen 20 mm. wide on the hinge line has the acute angles located 3 mm. from the cardinal extremities.

The area of the dorsal valve is linear and its growth is arrested very early in the development. The deltidium of the youngest specimen which retains it has already been described. Specimens under three or four mm. in width usually show the strong, convex deltidium prolonged below the beak and within the margin of the neionic shell, to form a tube for the passage of the pedicle. In many cases the upper part of this tube is broken away near the surface of the shell and what remains of it appears as a rather stout conical tube with a large opening (Figs. 18, 19, 20).

In a few specimens the entire tube is retained. It then rises about 2 mm. above the beak, tapers gradually, and is perforated by a minute pore at the apex. In older specimens, 5 or 6 mm. in width, the scar of the base of this tube can be seen on the ventral beak and inside the circle formed by it there is a minute pedicle opening. In later stages the opening is hard to detect and seems to be closed entirely in adult specimens.

In no stage is there much open space at the lower end of the delthyrium. As the cardinal process increases in size it projects more and more beyond the dorsal beak and the deltidium becomes correspondingly convex, so that the two fill the delthyrium completely. The deltidium is, in some cases, grooved in such a way as to conform to the shape of the posterior face of the cardinal process.

The cardinal process is large, bilobed as seen from the front, and quadrifid on the posterior face. It is supported by the lamellæ of the dental sockets which rise rather abruptly as thin curved plates and run transversely under the umbo, curving backward to join the cardinal process. There is little change in the form of the process during life, except that it curves more backward and upward in the later stages until it comes up close to the beak.

In the ventral valve the delthyrium is limited by two strong dental lamellæ which extend slightly beyond the hinge line. In young and adult stages they are unsupported, but in gerontic shells they are braced by two outward curving plates which connect them with the inside of the shell at the umbo.

The Same Species in Other Localities.

The specimens from Pompey Hill, N. Y., are all small. The largest is 17×25 mm. and the smallest 8×12 mm. A specimen 13×19.5 mm., which is of average size for this locality, has 100 striae. The dorsal valves of these specimens are nearly flat, and the ventral valves low, but distorted about the umbo.

The specimens from Pratt's Falls, N. Y., are of about the same size and proportions. The smallest is 5×7 mm. Another is 8.5×12.5 mm. and has 70 striae. A third is 13×20 mm. with 110 striae and the largest specimen is 17.5×23 mm. These specimens have very low cardinal areas and are hardly at all distorted.

The specimens from both localities belong to the variety *arctistriatus*.

Ortothetes bellulus Clarke. (Plate V, Row 3.)

Clarke, 13 An. Report N. Y. State Geol., 1895, pp. 176, 187, pl. 4, figs. 2-4.

This species is represented by a less complete series than *O. cheymungensis*. The range in size is from 1.4×2.3 mm. to 10×14.5 mm. Between these limits there are specimens which show all stages up to the adult condition, but none show senile characters and probably the normal size of the adult is not attained, judging from the case of the other species of this genus.

The individuals figured by Clarke differ in minor respects from the present specimens and a portion of his description of the Marcellus species is quoted. "This species is of persistently small size and quite regular in form, none of the specimens showing umbonal distortion. The valves are transversely elongate, the hinge line forming the greatest diameter. The surface is covered with eighteen or twenty sharp, narrow, distant plications, . . . -and in the middle of each of the broad interspaces is a smaller and usually obscure rib: rarely two of these ribs are present. The length of an average specimen is 10 mm.: its diameter along the hinge is 15 mm. This is from the limestone of the Marcellus division at 854 feet in the (Livonia Salt) shaft."

Nepionic Stage. — The shell is very small in the nepionic stage. It is almost circular, biconvex and smooth. The diameter is from .10 to .12 mm. as preserved on the beaks of dorsal valves from 1.4 to 3 mm. in length.

Changes During Development.

In the earliest stage in which striae appear there are from eleven to fifteen. New ones are added by intercalation at an early stage so that the smallest specimen, 1.4 mm. long, has 18 striae. In the adult there are from 24 to 30. In all other characters than the striae the development is the same as in *O. chemungensis*. The index is very constant, for, neglecting the neanic stage where it is practically 1, it varies from 1.25 to 1.50.

Specific Characters of the Shell.

As Developed in the Upper Hamilton. — Biconvex or plano-convex, transversely elongate, with a hinge width less than the greatest width below. Area of ventral valve high, frequently distorted. Dorsal area linear. Delthyrium completely closed by a very convex deltidium, which, in young stages, is prolonged into an exert pedicle tube. In the adult the pedicle passage is closed.

Surface marked by 24 to 30 strong simple plications, which increase by implantation. Between them are spaces which are wider than the plications. Very numerous concentric lines cover the entire surface. Shell substance highly punctate. The punctæ lie in double rows between the plications.

A species, which, if not identical with this, is at least very closely related, is *Orthothetes flabellus* White, from the Upper Helderberg of Columbus, Ohio. This species is larger than the specimens in the present collection and has the greatest width at the hinge. The striae, which are simple, number 22 or 24 and are separated by wide concave interspaces. The specimen figured is 22 mm. long and 26 mm. in width.¹

Orthothetes : Summary. — The development of two other species of *Orthothetes* has been worked out. That of *O. subplanus* of the Niagara by Beecher and Clarke² and of *O. minutus* of the Salem Limestone by Cumings.³

O. bellulus has in its adult stage many characters which agree with the neanic stages of *O. minutus*. That species has in its earliest plicated stage eighteen plications and more are added in the same way

¹ See *Annals N. Y. Acad. Sci.*, 1891, p. 521, pl. 6, figs. 7-9.

² *Memoirs N. Y. State Museum*, Vol. I, No. 1, 1887.

³ *Orthothetes minutus*, *Am. Geol.*, Vol. XXVII, March, 1901, p. 147, pl. XVI, figs. I-II.

as in *O. bellulus*. In the adult, dwarfed, 4×5.5 mm. there are 40 plications.

Comparing the development of *O. chemungensis* with that of *O. subplanus* of the Niagara we find many differences.

1. In convexity of valves. The neionic shells of *O. chemungensis* have the valves subequally convex, which is the adult state in *O. subplanus*, while its neionic shell is concavo-convex.

2. In *O. subplanus* the cardinal area is low compared with the length of the hinge line and the adults are symmetrical. In *O. chemungensis* only in the early neanic stages are the shells perfectly symmetrical in most cases, though some specimens with low cardinal areas retain their symmetry into late neanic stages.

3. In surface characters. The duration of the neionic stage is about the same in both species. In the youngest specimen of *O. subplanus*, figured by Beecher and Clarke, 2.25 mm. long, there are seventeen striae, six of which are secondary. A specimen of *O. chemungensis* of similar length has from twenty-eight to thirty-five striae.

4. Hinge structure. The young of both species have a strong convex deltidium which is prolonged into an exert tube for the passage of the pedicle. In *O. subplanus*, the deltidium ceases to grow at an early stage, while in *O. chemungensis* it continues to increase in size throughout the life of the individual.

The first three of these differences point to an earlier acquisition of the characters through acceleration. The last would tend to show that *O. chemungensis* was in a progressive rather than a retrogressive line of development.

***Chonetes coronatus* Conrad.** (Plate VI, Rows 3 and 4.)

Hall, Pal. N. Y., IV, 1867, pl. 21, figs. 9-12.

This is the least common of the three described species of *Chonetes* so abundant in the silicified material. About five hundred good specimens were obtained, nearly all of them detached valves. Ventral valves are the more common and also the better preserved. All gradations from specimens 1.2×1.3 mm. to those 15.4 by 23 mm. are found, while from a study of the umbos of the small specimens still younger stages can be made out.

The smallest specimen figured by Hall is 10.8 mm. long and 14 mm. wide. The largest is 22 by 41.5 mm.

Nepionic Shell. — In the nepionic stage the shell is almost circular in form, the hinge line slightly curved and almost as long as the greatest width below. Both valves are convex, the ventral more so than the dorsal. In the ventral valve there is a narrow, well defined sinus, and a corresponding fold occurs in the dorsal shell. The length of the nepionic shell varies from .30 to .45 mm. and the width is slightly greater (Fig. 24).

Changes During Development.

Outline. — The outline of shells less than 2 mm. in length is quite variable. In some, the length nearly equals the width, while others are from one-third to one-half wider than long. In general, the shell becomes wider, in proportion to its length, as it grows older. The index varies from 1.09 to 1.49. Shells less than 6 mm. wide usually have an index of less than 1.30. In the larger shells the index averages about 1.40. From the beginning of the neanic stage the hinge width equals or exceeds the width below. In adult and senile specimens the greatest width is below the hinge.

Convexity of Valves. — The ventral valve is moderately and evenly convex throughout all the stages. The dorsal valve is convex during the nepionic stage, but becomes concave immediately in front of the smooth part of the shell and continues slightly concave to the front.

Striae. — The smallest plicated shell seen has eight strong striae on the dorsal valve and nine on the ventral. The shell at this stage, is .65 mm. long and 1.00 mm. wide. The first striae on the dorsal valve appear to be formed by the bifurcation of the fold of the nepionic shell, and on the ventral valve the first four are formed by the bifurcation of the two ridges which bound the sinus in that valve. Then four more striae are added on each valve, two on each lateral margin and two striae are implanted on the dorsal valve, just outside the two striae formed by the bifurcation of the dorsal fold. A single striation is implanted in the sinus of the ventral valve as the ventral shell conforms to the depression in the dorsal shell, caused by the bifurcation of the fold. From this point, striae are added on the lateral margins until there are twelve or fourteen on the dorsal valve and thirteen or fifteen on the other. At this stage, the shell is usually about 3 to



FIG. 24. *Chonetes coronatus* (Conrad).

Dorsal valve of a young specimen, showing protogulum, nepionic shell with dorsal fold, and the shell of the pauciplicate neanic stage. The radial lines represented crests of the plications. . 9.

3.5 mm. long and 4 to 4.5 mm. wide. Then the striae begin to increase by both bifurcation and implantation. During the latter neanic stages there are from 30 to 60 striae and, in the adult, 80 to 100.

The implantation of new striae seems to be due to a mechanical cause, namely, the thinness of the shell. When the striae on one valve bifurcate, a depression is, of course, formed between them. As the other shell conforms to this irregularity on the frontal margin, a single stria is produced. The increase of striae by implantation does not seem to be confined to either valve, but occurs on both. One specimen, in which bifurcation of the striae has just begun, shows this process well. On the dorsal valve there are twelve primary striae, one of which, near the middle of the valve, has bifurcated. On the ventral valve there are thirteen striae, two of which have bifurcated. On the dorsal valve, there are two implanted striae which correspond in position to the depression between the bifurcated striae on the opposite valve, while on the ventral valve there is one implanted stria corresponding to the bifurcated one on the dorsal valve. There is, however, nothing regular in the number of implanted and bifurcated striae on each valve, for, as Hall has remarked, sometimes one valve will have almost all of its secondary striae added by implantation and again by bifurcation, or by both ways in all proportions.

Hinge Development. — In the early stages the area of neither valve is well developed and the shell is so fragile that no traces of the deltidium or chilidium are preserved in any of the small specimens. In the latter neanic and adult specimens there is a narrow cardinal area on each valve. That of the dorsal valve is about one half to three fourths as wide as the ventral area. Covering the apical portions of the delthyrium there is a convex deltidium, while the larger part is filled by the cardinal process. No pedicle opening was observed.

On the dorsal valve there is a narrow chilidium covering the posterior end of the cardinal process and the ends of the dental sockets. The cardinal process is strong, roughly triangular, deeply bifurcated, and each lobe is again divided by a shallow groove.

In the ventral valve there are two strong striated teeth rising in front of, and below, the cardinal area. They curve upward and inward. In the dorsal valve there are deep grooves on each side of the cardinal process which are bounded on the inside by slight projections from the process and on the outside by strong diverging lamellæ. The articulation appears to be the same as in *Tropidoleptus*.

Muscle Scars.—The scars of the muscles are so faintly impressed in young specimens, that they cannot be made out. In the ventral valve of the adult are two large flabelliform diductors and between them the narrow elongate scars of the adductors, one on each side of the median septum. The scars of the muscles attached to the dorsal valve are described under *C. mucronatus*. Outside the scars, in this valve, the whole surface is covered by numerous radiating rows of small, sharp, forward-pointing pustules.

Spines.—The number and place of appearance of the spines varies somewhat in the different individuals, and the bases of the earlier spines become so obscured that it is often difficult to recognize them.

On most individuals with a hinge width of 3 mm. there are 6 spines. On individuals in most of the neanic stages there are 6 to 14 spines; on adults, 14 to 20. In this reckoning, spines and spine bases from which spines have been broken or worn, are counted as spines.

The spines do not appear in exactly symmetrical positions on each side of the beak and there are not always the same number on each side, though usually there are. The departure from the symmetrical is not great, varying from a few hundredths of a millimeter, near the beak, to 1 or 2 mm. in case of spines near the cardinal angles.

The first spines appear about .25 to .35 mm. from the beak, the second .54 to .75 mm. and so on. The averages of a number of measurements are: For 1st pair, .30 mm.; 2d, .62 mm.; 3d, 1.10 mm.; 4th, 1.62 mm.; 5th, 2.32 mm.; 6th 3.11 mm.; 7th, 4.81 mm.; 8th, 6.16 mm.; 9th, 8.08 mm.; 10th, 10.5 mm. It would seem that, in many cases, certain of the spines were suppressed. For instance, in one specimen 8 mm. wide, there are only six spines. The first pair is .66 mm. from the beak, the second 1.5 mm., and the third 3.3 mm. Comparing these measurements with the averages given above we find that these spines are the second, fourth and sixth pairs. Very likely the first pair was formerly present, but are so entirely broken away as to leave no trace. In all specimens examined the second pair could be seen, and, in nearly all, the third pair.

The spines make a small angle with the cardinal line, usually less than 45°. The variation is from 18° to 43°, and the average is about 35°.

The Same Species from Other Localities.

Specimens from Sheldrake, Cayuga Lake, N. Y., are larger than the specimens just considered. An average specimen is 20 × 29 mm. and has 150 striae. There is a broad shallow sinus in the ventral valve.

The individuals in the material from East Bethany, N. Y., also average larger than the Canandaigua Lake specimens. The largest specimen is 21.5×30 mm. and has 125 striae. The smallest is 10×15 mm. with 50 striae and five pairs of spines. A specimen of about the same size from the silicified material has 80 striae. These specimens do not show the sinus in the ventral valve.

The Eighteen Mile Creek, N. Y., specimens are more clearly the size of the individuals from Canandaigua Lake. The smallest is 11×15 mm. with 54 striae. A larger one is 15.5×23 mm., with eight pair of spines and 82 striae. The largest specimen is 18×25 mm. Some of these shells show a sinus in the ventral valve and a fold in the dorsal valve. Others do not have either.

Chonetes scitulus Hall. (Plate IV.)

Hall, Pal. N. Y., IV, 1867, p. 130, pl. 21, fig. 4.

Of this species there are about 3,500 specimens, among which are individuals showing all stages of development. The smallest shell is .93 mm. long and 1.01 mm. wide. The largest 6 mm. long and 9 mm. wide.

The smallest specimen figured by Hall, is 7×9 mm. and the largest (from the Hamilton) is 8.4×12 mm. The Chemung specimens are, according to that author, usually larger. A figure of the protegulum of this species has been published by Beecher (*Am. Jour. Sci.*, Vol. XLI, 1891, p. 357, pl. 17, fig. 14). It is oval in outline, slightly longer than wide, and has an arcuate hinge.

Nepionic Shell. — The nepionic shell is subcircular in outline with a hinge width a little less than the greatest width below. In the ventral valve there is a narrow, shallow sinus, bounded by two ridges. In the dorsal valve there is a median fold which extends to the beak and, on either side, a lesser fold which does not reach the beak nor join the median fold. The lateral folds are less distinct than the median one and die out toward the front.

The length of the shell at this stage varies from .42 to .56 mm. On a specimen from Thedford, Ont., the ventral shell at this stage is .42 mm. long and .46 mm. wide.

Changes During Development.

Outline. — Until the shell reaches a length of about 1.5 mm. the length and width are nearly equal, and the index is from 1.08 to 1.20.

There is no great variation from this outline during the life history, although some individuals have unusual proportions. The average index, for adult specimens, is about 1.30.

Convexity of Valves. — In the nepionic stage the ventral valve is slightly convex. The dorsal valve is convex for about half its length and then becomes concave. The ventral valve is only moderately convex in the earlier neanic stages, but in later neanic and ephebic stages it becomes strongly so. The dorsal valve follows the contour of the opposite one quite closely.

Striae. — The smallest shell, a ventral valve, shows six striae. Each of the ridges which bounds the median sinus divides, making four striae, and one is added on each margin. In the next stage a stria is implanted in the sinus and two more are added on the lateral margins, making nine in all. The smallest dorsal valve in the collection, 1 mm. long and 1.12 mm. wide, shows a condition corresponding to this stage. It has eight striae, the middle pair of which originated by



FIG. 25. *Chonetes scitulus* Hall; ventral and dorsal valves, showing fold and sinus and plications of very young specimens. — 12.

the bifurcation of the median fold of the nepionic shell. In the next stage, four more striae are added, on each valve, outside the older ones, making 12 on the dorsal and 13 on the ventral valve. From that point new striae are added in front by implantation and bifurcation. The whole process is the same as in *C. coronatus*. The adult shell has from 30 to 40 striae, counted on the anterior margin.

Hinge Development. — The area is narrow on both valves. That of the dorsal valve is a little more than half as wide as the ventral area. In one adult specimen, the ventral area was .44 mm. wide at the apex and the dorsal area, .25 mm.

The delthyrium is wide, the upper third covered by a convex deltidium and the remainder filled by the cardinal process. The deltidium continues to grow throughout life but is so curved back in its lower part that the cardinal process fills the larger part of the opening. No pedicle opening has been observed on the specimens in this collection. On the dorsal valve there is a very narrow chilidium at the apex, covering the base of the cardinal process. In nearly all speci-

mens it is much eroded, as is also the outer face of the process. The cardinal process is about as wide as long and bifid. The posterior face is divided only once instead of into four parts as in *C. coronatus*. At the sides of the process are deep sockets, and in the ventral valve strong striated teeth. The same arrangement for articulation can be seen in a specimen one mm. in length, and seems to undergo no modification during development.

Muscle Scars. — In the ventral valve, the muscle area consists of two very large flabelliform diductor impressions, between the posterior ends of which are two oval scars of the adductors, one on each side of a thin septum. The interior of the brachial valve is described under *C. mucronatus*.

Spines. — Individuals over 1 mm. in length have two pairs of spines on the ventral valve. At 3 mm. in width there are four pairs. As in *C. coronatus* the spines near the beak are represented on the adult shell by the bases only. The average distances of the spines, from the beak, are as follows: 1st pair, .28 mm.; 2d, .55 mm.; 3d, .96 mm.; 4th, 1.41 mm.; 5th, 1.73; 6th, 2.18; 7th, 2.91; 8th, 3.69.

The spines of this species are more erect than in any of the others here described. They project at angles of from 45° to 70° with the hinge.

The Same Species from Other Localities.

Specimens from Pratts Falls, N. Y., are, on the average, somewhat smaller than those just discussed. The smallest specimen is 2.2×3 mm. and has 19 striae. The largest is 5.5×8 mm. with 30 striae. The spines extend out at angles of from 60° to 70° with the hinge. On one specimen the outer spines are 2.5 mm. long.

The material from Eighteen Mile Creek contains many individuals, some of which are larger than those from Canandaigua Lake. The smallest specimen is 4×5 mm. and the largest 9×12 mm. The number of striae varies from 27 to 60. An average specimen is 7×11 mm. and has 53 striae.

The specimens from Thedford, Ont., are of about the same size and shape as the silicified specimens, but have more striae. They range in size from 5×7 mm. to 7×9 mm. and an average individual has about 44 striae. Many of the adults show all stages of growth, beginning with the nepionic.

Chonetes mucronatus Hall. (Plate V, Rows 4 and 5.)

Hall, Pal. N. Y., IV, 1867, pl. 20, fig. 1, pl. 21, fig. 1.

Of this species there are about 1500 specimens in the collection, nearly all of them detached valves. All stages of growth are shown. The smallest specimen is 1.09 mm. long and 1.13 mm. wide; the largest, 11 mm. long and 13 mm. wide. Hall does not illustrate any specimens of this species from the Hamilton. Those that he figures from the Corniferous and Marcellus are smaller and less convex than the major part of the adults in this collection. The smallest specimen figured by him is 5.6×6.8 mm. and the largest 6.4×8.2 mm.

Nepionic Shell. — In the nepionic stage the shell is subcircular in outline, the ventral valve convex, and the dorsal valve convex at the umbo and concave in front. There is a faint median sinus in the ventral valve, but the ridges bounding it are not as strong as in the other species. On the dorsal valve there is a sharp median fold which extends only about half way to the front and then dies out. Faint traces of a pair of lateral folds can be seen. The size of the shell at this stage varies in the different individuals. For one specimen the dimensions are: length .59 mm., width .62 mm., width of the hinge .56 mm., length of the dorsal fold .37 mm. In other specimens the nepionic shell reaches a length of .75 to .90 mm.

Changes During Development.

Outline. — At the beginning of the neanic stages the hinge length becomes as great, and then greater than the width below and remains greater until senile characters begin to appear. In all stages the width of the shell is somewhat greater than the length. The greatest excess of width over length occurs in the later neanic and early ephebic stages when the index is about 1.30 to 1.40 mm. In the earlier neanic stages the index is 1.10 to 1.20 mm. and with the accession of the gerontic characters it falls to 1.25 mm. or even less.

Convexity of Valves. — In the neanic stages the ventral valve is very moderately convex and the dorsal valve slightly concave, often nearly flat. In the adult and gerontic stages the ventral valve becomes strongly convex and finally gibbous. The dorsal valve is rather strongly concave a little anterior to the middle.

Striae. — Owing to the low, rounded, often indistinct character of the striae, it was not possible to make out clearly all the steps by which

the striae are introduced in this species. A ventral valve 1.41 by 1.59 mm. has seven striae, one of which originates on the median line somewhat later than the others. A larger specimen, 1.72 \times 2.06 mm., has nine striae. A dorsal valve of about the same size, 1.72 \times 2 mm., has eight striae, two of which, in the middle of the valve, are longer than the others, but do not seem to join the median fold of the nepionic shell. After this stage more striae are added at the lateral margins and, occasionally, by bifurcation and implantation, but the number is, at all stages, very irregular. One specimen, 3 \times 4.23 mm., has 14 striae, while one, 4.30 \times 5.61 mm., has only 9. In the adult stage there are from 25 to 40.

Hinge Characters. — The area on both valves is narrow, that of the dorsal valve being about one half as wide as the other. In all stages the delthyrium is closed by a convex deltidium which covers about two thirds of the opening. The chilidium on the dorsal valve is nearly as wide as the greatest width of the cardinal area.

Muscle Scars. — In the ventral valve are the two large flabelliform scars of the diductors and between them the smaller adductor scars. In the dorsal valve, just anterior to the cardinal process, are two small oval scars, and, between them, a pair of slightly larger scars separated by a low rounded septum. In front of these adductor scars are large brachial areas which extend nearly to the anterior margin of the shell. Each brachial area consists of two parts. On the outside there is a rather strongly marked reniform impression which begins just outside the muscular area and extends around to the front of the shell. Within the crescent formed by this impression is a raised portion, which is smooth and limited on its inner side by a ridge.

These ridges originate at the sides of the median septum at about the middle of the muscular area and extend three fourths of the distance to the front of the shell, diverging at only a small angle from the median septum. At their anterior ends they are usually high and sharp, terminating rather abruptly.

Chonetes scitulus and *C. coronatus* have the same markings on the interior of their dorsal valves, but they are less deeply impressed. In *C. coronatus* the middle (anterior) pair of muscle scars are long and narrow, while the outer pair are larger and roughly rectangular. The brachial areas can hardly be divided into two elements in the majority of the specimens of this species, and in the young individuals no impressions at all can be made out. The diverging ridges on each

side the median septum are low and do not end in prominent projections.

In *C. scitulus* the ridges are very prominent and usually pustulose. The muscle scars are not strongly marked, but the reniform part of the brachial impression is deeply excavated and is limited by concentric rows of strong pustules. In front of these rows of pustules all around the margin of the inner surface of the shell there is a border which is almost smooth.

Spines.—The spines on this species are better preserved than on any of the others in this material. They are larger and coarser, and are also protected by lying against the shell and each other. The smallest shells in the collection show the bases of two pairs of spines, and the adults show remains of from four to seven pairs. The average distances at which they emerge are as follows: 1st pair, .53 mm. ; 2d, 1.16 mm. ; 3d, 2.01 mm. ; 4th, 2.54 mm. ; 5th, 3.41 mm. ; 6th, 4.40 mm. ; 7th, 5.53 mm.

Gerontic Stage.—With old age the shell becomes greatly thickened, the muscle scars more deeply impressed, there are numerous strong varices of growth near the margin, and the striæ become faint or entirely obliterated in the front. The shell becomes gibbous, the width below becomes greater than that at the hinge, and there is a constriction just in front of the cardinal area which gives a sort of auriculate appearance to the cardinal extremities. When this occurs the plane of the ventral area is revolved inward from its normal position.

Comparison with Specimens from Other Localities.

The specimens from Pompey Hill, N. Y., have about the same size and index as the above, but usually have fewer plications. A specimen 7.5×10.5 mm. has 18 plications, and one 7×9.5 mm. has 22, while individuals of that size from Canandaigua Lake have from 25 to 30. The largest specimen is 10×14 mm. and the smallest 4×5 mm. The index in adults is from 1.22 to 1.40 mm.

Three specimens from Pratt's Falls, N. Y., are of fair size, 8×11 mm. to 9×12 mm., and have from 22 to 30 striæ. The spines extend nearly parallel to the hinge.

In the collection there are numerous specimens from Eighteen Mile Creek, most of which are smaller than the average specimens from Canandaigua Lake. The largest one is 8×13 mm. with 35 striæ, and the smallest is 5.5×8 mm. An average specimen is 7.5×10 mm.,

and has from 25 to 28 striae and six pairs of spines. Except in a few specimens showing senile characters, the hinge width is the greatest width of the shell.

***Chonetes robustus* Raymond.** (Plate 7, Rows 1 and 2.)

Am. Jour. Sci., Vol. XVII, p. 289, pl. XVII, Rows 1 and 2, April, 1904.

This species is represented by specimens in the neanic and epibiotic stages only, so a complete developmental series could not be obtained. The smallest specimen is 2.6 mm. long, and 3.2 mm. and the largest 11.06 \times 14.33 mm.



FIG. 26. *Chonetes robustus* Raymond. Ventral valve of a typical specimen from the writer's collection. $\times 2$.

narrow median sinus. In one specimen the dorsal fold extends for .60 mm., and in another .66 mm., so the neionic shell was probably of about that length.

Changes During Development.

Outline. — The outline of no shell less than 1.93 \times 2.92 mm. can be made out, so the list of changes is very incomplete. Until the shell reaches 6 mm. in length the index is very constant at about 1.40. Older shells have the length and breadth a little more nearly equal and the index falls to 1.20 in the largest shell in the collection. In most of the specimens the width of the shell at the hinge, is greater than the width below, but in two of the largest individuals it is a little less.

Convexity of Valves. — The ventral valves of the younger shells are only slightly convex, but in mature specimens they become very strongly so. The dorsal valve is flat or slightly concave in the younger stages, but is strongly concave toward the front in adults.

Striae. — One of the neionic characters, the absence of striae, continues into the early neanic stages. In some individuals this smooth state is retained longer than in others. The largest smooth shell is a dorsal valve 3.16 mm. long and 3.4 mm. wide. On another this

smooth character extends for a length of only 1 mm. and there are many specimens which are between these limits.

In the earliest plicated stages seen, there are 12 striae on the dorsal valve and 13 on the ventral. One specimen showing this stage is 5.15 mm. long and 6.38 mm. wide. The striae are all simple and the ones in the middle are longer than those on the sides. Other smaller specimens show this same number, or, in some cases, more striae. A specimen 1.93×2.92 mm. shows 15 striae. A dorsal valve 5.13×7.66 mm. shows 16 simple striae, and a ventral valve, 6.46×7.93 mm. has 19. On specimens larger than this new striae are added by bifurcation or by the implantation of new striae between older ones. The highest number on any of the shells was 36 and the usual number for adults is 20 to 30.

Character of Hinge. — The area of the ventral valve is narrow in the adult, but about twice as wide as that of the dorsal shell. The delthyrium is rather narrow and is completely covered by the slightly convex deltidium. A pedicle opening can be seen in one or two of the adult specimens. On the dorsal valve there is a chilidium posterior to the dental sockets and cardinal process.

Muscle Scars. — In the ventral valve are the large, flabelliform impressions of the diductor muscles, and the narrow, elongate adductor scars. In the dorsal valve the middle pair of adductor scars are elongate oval, and situated on a sort of platform just in front of the cardinal process. On either side and at a lower level are the rounded outer scars. The brachial impressions are large and rounded and their limit is marked by a single row of pustules. The medium septum and the two lateral ridges are faintly marked.

Spines. — Owing to the small number of ventral valves the position of all the spines could not be determined as satisfactorily as with the other species. Ten specimens were measured and the averages are as follows: 1st pair, .47 mm. from beak; 2d, .96; 3rd, 1.29; 4th, 2.03; 5th, 3.30; 6th, 4.24; 7th, 5.61; 8th, 6.16; 9th, 8.33. Thus if all the spines were developed on one individual, there would be nine pairs, but the specimen in this collection which bore the greatest number had only six pairs and the majority of them had only 4 or 5 pairs. The spines stand out at about the same angle with the hinge as do those of *C. coronatus*. The limits were 21° and 40° , but the average was above 30° .

Same Species in Other Localities.

There are three specimens in the museum collection from East Bethany, N. Y., which are labelled *C. mucronatus* but whose sharp, distant striae and smooth umbos show that they belong to the species here described. One is 6×8 mm. and has 20 striae; a second is 6×9 mm. with 24 striae and the largest is 8×10 mm. and bears 22 striae and 4 pairs of spines. They are slightly less gibbous than the Canandaigua Lake specimens but are in other respects the same.

On the beak and umbo of the ventral valve of one specimen are growth lines marking the early stages. The smallest of these is .35 mm. long and .41 mm. wide and the next is .65 mm. long and .91 mm. wide. There is a narrow sinus which does not extend quite to the second growth line but that line probably marks the limit of the nepionic shell. It is slightly convex, and the hinge width is about equal to the width below.

The plications begin beyond a line 2.2 mm. from the beak. At this stage the shell is 3.6 mm. wide, and the cardinal extremities are a little extended.

Chonetes : *Summary*. — All the species of *Chonetes* here described have, as would be expected, the same general type of changes in development. The different species are here compared at the various stages.

Protegulum. — The shell in this stage is exceedingly small, but in none of the specimens in the present material are the beaks well enough preserved to show it. From Beecher's work we know that in *C. scitulus* the protegulum is nearly circular in outline (.117 mm. long and .111 mm. wide, according to the figure) with a strongly arcuate hinge.

Nepionic Stage. — The species agree in having the shell at this stage convex in the ventral valve and convex at the umbo and concave or flat in front in the dorsal valve. This is an advance on the condition in *Strophodontia* where the dorsal shell was convex during the whole of the nepionic stage.

The ventral valve always has a narrow sinus and the dorsal valve a corresponding median fold and usually two less definitely marked lateral folds.

The outline is subcircular, though the width is usually a little greater than the length. The hinge is somewhat arcuate. The length of the

nepionic shell varies considerably in the different species, but is always less than 1 mm. It is least in *C. coronatus* and greatest in *C. mucronatus*.

Pauciplicate Neanic Stage. — In this stage new striae are introduced by implantation and not by the bifurcation of the older striae. The striae are strong, simple, and separated by spaces as wide as the striae. The number of the striae is not great. In *C. coronatus* and *C. scitulus* the largest number is usually 13 on the ventral valve and 12 on the dorsal. In the other species there are more, but usually less than 20.

The shell is about one fifth wider than long, and gently concavo-convex. The first spines (usually two or three pairs) appear during this stage. The size of the shell at the end of this stage, that is, when the striae begin to bifurcate, is least in *C. scitulus*, where it is about 2 mm. in length, and greatest in *C. robustus*, where it reaches a length of 6.5 mm.

Later Neanic and Ephobic Stages. — It would be difficult to make any sharp line which would mark the end of the adolescent period and the assumption of all the adult characters. The size, convexity of valves and number of striae continue to increase during these stages; the width becomes greater in proportion to the length and a number of pairs of spines are added on the cardinal margin.

Gerontic Stage. — Senile characters are not well shown except in *C. mucronatus*. In all, this stage seems to be accompanied by a thickening of the shell, a deepening of the muscle scars and a growth of the anterior part of the shell, which reproduces the early neanic condition of length almost equal to breadth; and an increase in the convexity of the ventral valve.

The simplest type of *Chonetes* would then seem to be one with a moderately convex ventral valve, the width a little greater than the length, the pedicle tube open at maturity, the surface covered with simple striae and with few pairs of spines. Of the species here discussed *C. robustus* is the most primitive in its character, as is shown by the continuation of the smooth state into the early neanic stage, the large size of the shell and the comparatively large number of striae acquired before the end of the "pauciplicate" neanic stage, and the retention of the open pedicle tube in the adult.

Of the species in the older formations, *C. cornuta* Hall of the Clinton and *C. undulata* Hall of the Niagara show some of the primitive

characters. Hall, in describing the former species in Vol. II, Pal. N. Y., p. 64, says: "Surfaces covered with fine equal striae which are equal to the spaces between them: striae round, straight, bifurcating. Three spines on each side of the beak. The species is more flat than the small one in the Corniferous and Hamilton group which it resembles." In the 11th Indiana Report, p. 293, Hall says of the same species: ". . . in *C. cornuta* the interstices are wider than the striae, and the latter increase only by interstitial additions below the middle of the shell." The size of the shell, according to Hall's figures, is about 4.2×5.5 mm.

Chonetes undulata, in the specimens figured,¹ has 21 simple striae on the ventral valve and is 3 mm. long by 4.75 mm. wide. In his description Hall says "Surface marked by obscure radiating plications which are broad and rounded below and obsolescent toward the beak: cardinal margin of the ventral valve ornamented by two diverging spines on each side of the beak. . . . The bases of two spines on each side of the beak are usually preserved and no specimen examined has more than that number."

Stropholasia truncata Hall. (Plate VII., Rows 3 and 4.)

Hall, Pal. N. Y., Vol. IV, 1867, p. 160, pl. 23, figs. 12-24.

Of this species there are about 50 good specimens in the collection.



FIG. 27.
Stropholasia
truncata

Hall; dorsal beak, showing protogulum and nepionic shell.
X 16.

There are about as many of one valve as of the other. The largest specimen is 8.33 mm. long and 10 mm. wide: The smallest 2.06 \times 2.69 mm. All of the specimens from this material are small for the species. The smallest specimen figured by Hall is 10 mm. long and 12 mm. wide while the largest is 17 mm. long and 18 mm. wide.

Nepionic Shell.—Owing to the deformation of the ventral beak and umbo resulting from the method of attachment, very little could be made out concerning that valve in the youngest stages except that it is regularly and moderately convex. The smallest ventral valve is 2.93 mm. long, and 3.33 mm. wide. The beaks of some of the dorsal valves are extremely well preserved and all stages from the protogulum to the adult can readily be observed. The protogulum is transversely oval, with a gently curved hinge. In the best preserved specimen it is .131 mm. long and .156 mm. wide (Fig. 27).

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¹ Eleventh Ann. Report, Indiana State Geol., p. 294, pl. 22, fig. 15.

The dorsal valve of the nepionic shell is subcircular in outline, with the hinge line equal to, or greater than, the width below. It is convex on the umbo and sometimes for its whole length, but is generally concave in front. The surface is smooth, without spines.

Changes During Development.

Outline.—The general outline remains much the same throughout life. In the later stages the width is slightly greater, in proportion to the length, than in the younger specimens. The index varies from 1.10 to 1.25. There are a few individuals with higher indices, one of 1.27 and one of 1.35. The length of the hinge is always less than the greatest width in all stages after the nepionic.

Convexity of Valves.—In the neanic stages the ventral valve is moderately convex and the dorsal valve convex at the umbo and concave in front. In the adult, the ventral valve is very strongly convex, while the dorsal valve is correspondingly concave toward the front.

Surface Markings.—There are no striae at any stage. After the nepionic stage, spines are developed on both valves, but more numerously on the ventral than on the other valve. On the dorsal valve they are generally broken off close to the base, but one specimen retains two of the spines, which are long, slender, and lie against the surface of the valve. On the ventral valve they are better preserved, in some cases most perfectly. They are most abundant along the cardinal margin and stand erect, curving in toward each other from opposite sides of the beak, suggesting that they might have been of use in anchoring the shell. Over the rest of the surface they are directed forward.

There is one dorsal valve, 3.66 mm. by 5 mm., which is devoid of any trace of spines. This may represent another species.

On all the dorsal valves there are, in addition to the spine bases, four or five pairs of wrinkles near the cardinal margin. Between them are pits which may represent the points of attachment of spines as wherever the spines of the dorsal valve have been detached shallow pits are left in the shell.

Cardinal Area.—The area of the ventral valve is narrow, from .5 to .75 mm. in width, and increases only a little after the shell has reached a length of 5 or 6 mm. The delthyrium is completely closed by a convex deltidium. Strong teeth bound the edges of the delthyrium. The dorsal area is about one third the width of that on the

ventral valve. There is a convex chilidium, at the apex of which is the minute anal opening. The inner opening of the anal tube is at the anterior base of the cardinal process, just in front of the point where it bifurcates. The cardinal process in the young stages is wider than long, projects little beyond the hinge line, and is divided once. In the adult it is longer than wide, deeply bifurcated in front and quadrifid on the posterior face. On each side of it is a dental socket which is bounded posteriorly by a slightly developed lamella.

Muscle Scars. — In the dorsal valve there are two pairs of small adductor scars, separated by a thin median septum which extends half way to the front of the valve.

In the ventral valve there are two small adductor scars and in front of them two larger diductor impressions. The scars are not strongly marked in either valve.



FIG. 28. *Rhipidomella vanuxemi* Hall : A ventral valve showing the comparatively large number of striae at a very early stage, and the smallness of the neionic shell. $\times 16$.

FIG. 29. The same species. Outline showing relative convexity of valves of a shell .58 mm. in length. Pedicel valve above. $\times 16$.

The largest shell of this species, figured by Hall, is 27 mm. long and 32 mm. wide. The smallest, 13.5×15 mm.

Neionic Stage. — The non-plicate shell in this species is extremely small, varying from .10 to .25 mm. in length. Both valves are convex, without fold or sinus. The outline is subcircular, the length and width nearly equal, and the hinge arcuate (Figs. 28, 29).

Changes During Development.

Outline. — In the early neanic stages the shell is wider than long and the frontal and posterior margins are nearly parallel, which gives the shell a pronounced transverse appearance. The index is from

1.30 to 1.40. In later neanic stages the length becomes more nearly equal to the width and a subcircular form is produced in the adult. The index is then 1.05 to 1.15. In the early neanic stages the width of the hinge is from .75 to .80 of the greatest width below. This proportion decreases rapidly and, in a specimen 3 mm. long the hinge is only .40 to .50 of the width below. This latter ratio is maintained throughout the succeeding growth stages.

Convexity of Valves.—The very young individuals, less than one millimeter in length, have the ventral valve slightly deeper than the opposite one, and specimens three or four mm. in length sometimes have the ventral valve twice as deep as the dorsal. In later stages the two valves become about equal in convexity and individuals above 10 or 12 mm. in length, at which stage the ventral valve is nearly flat in front, have the dorsal valve a little deeper than the ventral, reversing the relative convexity of the early stages.

With the first pair of plications a shallow sinus appears on the dorsal valve. It becomes broad and poorly defined in later neanic stages, and is hardly perceptible on the front of a specimen 12 mm. in length.

Striae.—The smallest individual in the collection has eight striae on the dorsal valve and seven on the ventral. On the dorsal valve, the middle pair bound the sinus and, since they are the longest, are evidently the first to appear. Outside of these the other six striae seem to have appeared at about the same time. On the ventral valve there is a median stria and three on each side of it. In the next stage observed there are twelve striae on the dorsal valve. Two of the new striae have been added on the lateral margins and two are implanted in the sinus between the first pair. From this stage striae are added rapidly by both implantation and bifurcation. A shell 1.33 mm. long and 1.75 mm. wide has 20 striae, ten of which are primary. At a length of 2.1 mm. there are 25 striae; at 5 mm., 50, and at 11.6, 80. This was the largest specimen on which the striae were sufficiently well preserved to be counted.

Hinge Development.—In the very youngest neanic stages the cardinal areas are about equal and the beaks diverge at a wide angle. The pedicle opening is shared by both valves, but the opening in the dorsal valve is somewhat modified by the small cardinal process. At a little later stage the cardinal process closes up the opening of the dorsal valve and in adult stages fills a large part of the opening in the ventral area. No traces of a deltidium are preserved on any of the specimens examined.

Inside the beak and umbo of the ventral valve is a thickening due to the deposition of shelly matter while the cardinal area is being added to. It is as wide as the area and striated in the same way. In young specimens this thickening shows as a concave plate at the apex of the delthyrium and might easily be mistaken for a deltidium.

In later neanic and adult stages the ventral beak is incurved, but does not project beyond that of the dorsal valve. The dorsal area remains nearly as wide as that of the opposite valve, but instead of lying at an angle as in the early neanic stages it is in the plane of union of the valves.

After the early neanic stages the teeth and crura are supported by lamellæ. The cardinal process is large and pyramidal, with the two posterior faces roughened for the attachment of muscles. The crura are long and slender, projecting outward and upward into the opposite valve. At the distal ends they are flattened vertically.

Comparison with Other Species.

The ontogeny of *Rhipidomella hybrida* of the Niagara has been worked out by Beecher and Clarke. (*Memoirs N. Y. State Museum*, Vol. I, No. I, 1889, p. 17, pl. I, figs. 13-18.) The two species agree closely in their developmental stages, one species differing only in the earlier assumption of the characters of each stage.

A shell of *R. hybrida* .5 mm. in length and .75 mm. in width has six striae on the dorsal valve and five on the ventral, while a specimen of *R. vanuxemi* .42 mm. long and .61 mm. wide has eight on the dorsal and seven on the ventral.

***Tropidoleptus carinatus* Conrad. (Plate VIII.)**

Hall, *Pal. N. Y.*, IV, 1867, p. 407, pl. 62, fig. 2, 3.

This well known species is very abundant in the silicified material, and a collection of about seven hundred well-preserved specimens was obtained after hundreds of fragmentary shells had been discarded.

The smallest shell is 1.66 mm. in length and 1.46 mm. in width, the largest, 22 mm. long and 28 mm. wide.

There are many shells showing all gradations between the two. Nearly all the small shells, and many of the adults, retain both valves in their proper relations.

The smallest shell figured by Hall is 4.6 mm. long and 4 mm. wide. The largest is 31 mm. long and 40.4 mm. wide.

Nepionic Shell. — In the nepionic stage the shell is transversely oval to subcircular, with a hinge width less than the width below. Both valves are convex and smooth. The hinge line is somewhat arcuate. In the early part of this stage the shell is distinctly wider than long, but just before the inception of the plications the length and breadth are about equal. Some of the dimensions are: $.14 \times .20$ mm., $.57 \times .64$ mm., $.66 \times .70$ mm., $.74 \times .74$ mm.

Changes During Development.

In Outline. — In the earliest neanic stages the shell becomes longer than wide and this form is maintained until the shell reaches a length of from four to seven millimeters, after which the proportions are reversed, and the width exceeds the length in succeeding stages. In the adult condition the shells are usually about one fourth wider than long. The index followed through all stages from the nepionic to the gerontic, shows a double curve. Thus: Nepionic, 1.42, 1.12, 1; neanic, .87, .81, .79, .85, .90, 1, 1.12; adult, 1.12, 1.18, 1.25; gerontic, 1.33.

From the early neanic through the adult stages the width of the shell at the hinge equals or exceeds the greatest width below. In these stages the cardinal extremities are usually mucronate. In gerontic stages the width continues to increase without a corresponding growth on the posterior margin, which produces rounded cardinal extremities and gives the shell a transversely elliptical shape.

Convexity of Valves. — Up to a length of from .75 mm. to 1.00 mm. both valves are slightly convex, the pedicle valve somewhat the deeper. At this point, where the plications generally begin the brachial valve becomes slightly concave, and in all later stages, is more or less concave beyond the growth line marking the end of the nepionic shell. In adult shells the dorsal valve is sometimes strongly concave, but is usually only moderately so, or nearly flat. From the earliest plicated stage the median plication of the ventral valve is somewhat stronger than the others and there is a corresponding sinus in the brachial valve. As the older stages are reached, this median

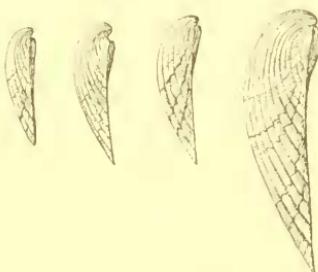


FIG. 30. *Tropidoleptus carinatus* Conrad. Series showing change in relative convexity of valves. $\times 9$.

fold and sinus becomes wider and finally forms a broad arch in the front of the valves.

Plications. — Immediately after the neopionic stage, plications arise on both valves and apparently several are formed simultaneously. On an individual 1.6 mm. in length there are ten plications on the dorsal valve and nine on the ventral. Another individual, of about the same size, has eight on the dorsal and seven on the ventral valve. New plications are added at the sides and are never implanted, nor do they ordinarily increase by bifurcation. In the adult there are from 17 to 21. In young stages the plications are sharp and distinct, but in the adult and senile specimens they are more rounded and become broad and faint in front. Two types of plications are found, one in which they are rounded, while in the other they are more angular and have wider spaces between. Fine concentric striae are very numerous.

Gerontic Stage. — The senile characters in this species are: hinge width shorter than the width below; strong varices of growth numerous; obliterations of the plications toward the front of the shell. One specimen showing these characters is 22 mm. long, 28 mm. wide, and has a width at the hinge of 16.2 mm. There are 19 plications on the ventral valve, all of which become flattened and obscure beyond a growth line at 12 mm. in front of the beak. In nearly all cases the plications are more completely obliterated on the dorsal than on the ventral valve. A larger specimen from East Bethany shows much the same character. It is 27 mm. long, 36.4 mm. wide, and has a width at the hinge of 22 mm. There are 19 plications, all of which become indistinct beyond a growth line 20 mm. in front of the beak. The shell is thickened and there are numerous strong growth lines near the front.

Other Features: Cardinal Area. — Each valve has a well developed cardinal area which is longitudinally striated. That of the ventral valve is a little wider than the opposite one and has a large triangular to semicircular delthyrium, the apex of which is rounded and encroaches somewhat upon the ventral beak. The cardinal process nearly fills this opening, but there is, at all stages, plenty of room for the emergence of the pedicle, which is probably functional all through life. The large and strong scar of the pedicle muscle also tends to support this view. No deltidial plates are found at any stage.

Muscle Scars. — The scars of none of the muscles show distinctly in either of the valves, except in the older stages. Then the scars of the

diductors become quite clearly defined in the ventral valve. They are large, flabelliform, and extend about half way to the front of the valve. They are limited posteriorly by a pair of ridges which extend outward from the bases of the teeth. Between the two diductors is a low rounded septum, on each side of which is a narrow oval adductor scar. Directly below the posterior ends of the teeth is a fairly deep pedicle muscle scar, often divided by the septum. Posterior to this, inside the beak, there is a continuation of the ventral area, of the same appearance and width as the external portions of the area. It serves to reinforce the umbo, which is encroached upon by the pedicle. This is the striated portion of the interior taken by Hall and Clarke (Pal. N. Y., Vol. VIII, pt. II, p. 302) for the attachment of the pedicle muscle.

In the brachial valve, the muscle scars are not well marked. The adductors are large, flabelliform, with faint radiating ridges dividing each into several parts. They extend over half way to the front of the valve, and a section shows that the shell is thickened, forming a platform for their attachment.

Cardinal Process. — The cardinal process is large and prominent. It extends into the delthyrium of the ventral valve, nearly filling it. The main part of the process is posterior to the hinge line. It is joined in front to the bases of the crura, and between them is a thickening of the shell, forming a platform which slopes down to the floor of the valve. On either side of this platform are the deep dental sockets which are crenulated on their posterior walls. In a large specimen the cardinal process is about 2.5 mm. wide. The posterior face is smooth and rounded, and the lower third is covered by a strong chilidium which also bounds the posterior ends of the dental sockets. The smallest specimen on which the chilidium could be seen was 3.5×2 mm. and the chilidium was .06 mm. in width. On a specimen 6×6 mm. it was .25 mm. wide and on an adult 1.5 mm. wide.

The posterior wall of the cardinal process has, near the top, a narrow rounded sinus and, in the bottom of this sinus, the shell is continued forward and downward until it unites with the platform of the process, thus forming a shelly loop. On either side of this loop is a deep conical hole which extends nearly to the apex of the shell and probably represents the place of attachment of the diductor muscles. Directly in front of the loop is a groove in the platform leading to a minute anal tube which runs through along the middle

line of the process and has its external opening in a pore just at the joint where the chilidium meets the apex of the valve.

Teeth. — In the pedicle valve, in front of the area, and separated from it by grooves, are two strong crenulated teeth which fit into sockets on either side of the platform of the cardinal process. These teeth seem to have practically the same form and position in all stages, but as they fit at such an angle in their sockets that it is almost impossible to separate the valves without breaking them, it is only rarely that a young specimen retains them. They have been seen in no specimens less than two mm. in length.

Septum. — In front of the bases of the crura there arises a rather thick, low, septum, which, about midway of the shell, increases abruptly in height till it reaches nearly to the opposite valve, then falls off less rapidly and terminates at a point which is about one fourth the length of the shell from the anterior margin. From the point where it begins to rise it is thin and sharp. This septum is well developed in young stages. A specimen 2 mm. in length has a septum exactly similar to that of the adult.

Brachidium. — Only a part of the loop has been seen in the present material. One adult specimen has two quite stout lamellæ which extend upward and slightly inward and reach about half way to the highest point of the septum. At their anterior ends they are flattened and turned slightly outward. Near the posterior ends are what appear to be the bases of processes which would have extended outward and upward. Another specimen, 2 mm. in length, shows about the same amount of the loop, but the two lamellæ diverge at a greater angle.

Punctæ. — The shells are very highly punctate, especially toward the front. From the point where the plications begin, up to a length of about three mm., the punctæ are confined principally to the depressions between the plications. There are two rows to each furrow. From that point they are scattered abundantly all over the surface.

The Same Fossil from Other Localities.

Calcified specimens from Ludlowville, Moscow, York, East Bethany and Eighteen Mile Creek, N. Y., were taken for comparison with the specimens in the present collection. Those from Ludlowville, York, and Eighteen Mile Creek resemble closely in size, index, and form, the specimens from Canandaigua Lake. Those from Moscow and

East Bethany are of larger size, have a higher index, and show a greater number of senile individuals.

The individuals from Ludlowville have, in the adult condition, the width of the hinge about equal to the width below, and most of them have the length nearly equal to the width, thus giving a low average index. The lowest index was 1.07 and the highest 1.33. The average of ten adults is 1.17. The largest specimen was 22 mm. long and 25 mm. wide. A single specimen showed, on one margin, two plications which had bifurcated in front of the last growth line. This is an unusual condition, although Hall figures a senile individual which has all the plications of the dorsal valve bifurcated in front. (Pal. N. Y., Vol. IV, pl. 62, Fig. 3e.)

The specimens from York are small. The largest one is only 19 mm. long and 22.4 mm. in width. The index, average of ten specimens, is 1.21. The range is 1.09 to 1.29.

In the collection from Eighteen Mile Creek there are specimens from 3.8 mm. by 3.2 mm. up to 20.4 \times 25 mm. The index varies from .84 to 1.30, and the average of ten adults is 1.22. The mature specimens retain a neanic character in having the median plication of the ventral valve only a little stronger than the neighboring ones. Many individuals have the strong angular type of plications.

From East Bethany there are numerous specimens ranging from 11 \times 13 mm. to 27 \times 37 mm. The index varies from 1.13 to 1.44 and the average for thirty-five specimens is 1.27. Of the 510 specimens examined, nineteen per cent. showed senile characters. These individuals are mainly larger than the average adults, but the index has almost identically the same range as in the adults, viz. 1.13 to 1.44 as compared with 1.13 to 1.42. There are in the collection from this place no distinct varieties, but the long forms, 22 \times 25 mm., index 1.13, grade by numerous intermediate steps into the wide forms, 19 \times 27 mm. index 1.42. The number of plications varies from 17 to 28. There are only a few specimens from Moscow, but they agree in proportion and form with those from East Bethany. The average of the indices is 1.24. The largest specimen is 26 \times 32 mm.

The facts would seem to indicate that, while the conditions at Canandaigua Lake were favorable for the production of large numbers of individuals of this species, they were not such as to allow them to reach the maximum development possible before the senile stage of their lives.

Trigeria lepida Hall.

Hall, Pal. N. Y., VIII, Pt. 2, 1893, pl. 50, figs. 36-40.

There are in the collection, about fifteen specimens of *Trigeria lepida*, three of which are adult individuals. The smallest specimen is 1.09 mm. long and .93 mm. wide: the largest is 6.8 mm. long and 6 mm. wide. The largest specimen is smaller than the smallest one figured by Hall. That is 7.8 mm. long and 6.7 mm. wide, while the largest is 11 mm. long and 9.5 mm. wide. According to that author, an adult has from 20 to 25 plications.



FIG. 31. *Trigeria lepida* Hall; young individual, before the inception of plications. $\times 16$.

Description of Smallest Specimen. — The smallest individual is roughly triangular in outline, the rostrate beak, which projects .25 mm. beyond the hinge, forming the apex. The ventral valve is convex and smooth without folds on sinus. The delthyrium is narrow and open. The dorsal valve is convex, nearly as deep as the ventral, and has a deep, narrow median sinus. There are no striae. This valve is oval in outline, and wider than long. The length is 84 mm., width .93 mm.

A narrow form, only a little longer than this, has the following dimensions. Length, ventral valve 1.36 mm., dorsal valve 1.20 mm., width 1 mm. In this stage the form is very suggestive of *Centronella* (Fig. 31).

Changes During Development.

Outline. — The outline changes very little during development, except in the amount of extention of the ventral beak. In the very small specimens, less than 2 mm. in length, the length of the ventral beak, behind the apex of the dorsal valve, is from .23 to .26 of the length of the shell. In older stages the beak is much less prominent. In a specimen 3.4 mm. long the beak is only .19 of the length, at 5.5 mm. long it is .15 and on the largest specimen, 6.8 mm. long, it is only .09 of the length (Fig. 32).

There are, in all stages, both broad and narrow forms. In the broad form, the index is about .85 in the young specimens and .90 in the adults. For the narrow forms it varies from .73 to .80. In the adults of the broad form, the dorsal valve is about as long as wide, and is only a little longer than wide in the narrow form.

Striae. — A specimen 1.87 mm. long has seven striae on the ventral valve. The median one is stronger and a little longer than the others. A specimen 3.4 mm. long has 15 striae and the largest specimen has the same number on the ventral valve and 14 on the dorsal. A smaller specimen, 3.46 mm. long, has 18 striae on the dorsal valve and another, 5.5 mm. long has 16 striae on one valve and 17 on the other.



FIG. 32. *Trigeria lepida* Hall; series showing the growth of the deltidial plates and the encroachment of the pedicle upon the ventral beak. $\times 8$.

Deltidial Plates. — None of the specimens less than 3 mm. long, show any traces of deltidial plates. The specimen 3.4 mm. long shows a very narrow scalene triangle on each side of the delthyrium. In the specimen 5.5 mm. long these triangles have become wider at the base, almost uniting. The apex of the ventral beak is encroached upon, thus enlarging the opening posteriorly. In the largest specimen the deltidial plates are still wider at their lower ends and are united for a short distance. The pedicle has encroached still further upon the ventral beak, forming a large oval opening.

Sinus. — The sinus in the dorsal valve is still sharp and distinct in a specimen about 3.5 mm. long, but, on the larger specimens, it is hardly perceptible.

Eunella lincklæni Hall.

Hall, Pal. N. Y., IV, 1867, p. 397, pl. 60, figs. 49-65.

Of this species there are about forty whole specimens retaining both valves and nearly as many separate valves. The smallest specimen is 1.17 mm. long and .84 mm. wide; the largest 19 mm. long and 17 mm. wide. So perfect is the preservation that in many cases a large part of the delicate loop which supported the brachia is preserved and, in at least one case, the loop is entire and as well shown as in the most perfect recent brachiopods of this type.

Description of Smallest Shell. — No stages earlier than that represented by the smallest shell in the collection could be made out. At that stage the shell is about three-fourths as wide as long, and the two

valves are subequally convex, the ventral valve a little the deeper. The dorsal valve is elongate oval, .87 mm. long and .84 mm. wide, while the ventral valve has a narrow rostrate beak which extends .2 mm. back beyond the hinge. The delthyrium is large, triangular and without deltidial plates (Fig. 33). The loop of this specimen can not be determined as only a short portion is retained. On the dorsal beak the first puncta can be seen and their arrangement agrees with that seen on the neionic shell of *Terebratulina septentrionalis*.¹

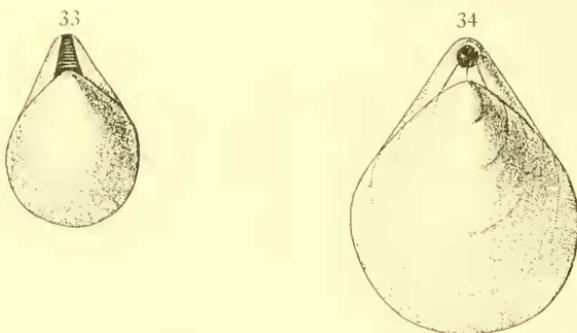


FIG. 33. *Eunella linckaei* Hall. Young specimen with open delthyrium. $\times 16$.
FIG. 34. The same species. An adult, showing several growth stages. $\times 3$.

The first pair of puncta are .072 mm. from the beak and in front of them, on the median line, and .109 mm. from the beak, is a third one. Beyond this they are scattered sparingly over the surface for a short distance but toward the front of the shell they become very numerous.

Changes During Development.

Outline. — The outline changes very little during the various stages. There are both broad and narrow forms. The index of the ventral valve varies from .68 to .88 in young specimens and from .76 to .92 in adults. The dorsal valves of adults of the broad type are nearly circular, while the index of the same valves in the narrow form is from .71 to .88.

Convexity of Valves. — In young stages the ventral valve is slightly deeper than the dorsal, but in the adult the convexity of the valves is often reversed. The ventral beak extends straight beyond the hinge in young individuals. In adults the umbo is incurved and the apex of the beak is truncated by the pedicle opening.

¹E. S. Morse, *Memoirs Boston Soc. Nat. Hist.*, Vol. V, No. 8, 1902, pl. 62, fig. 15, also *Mem. Bos. Soc. Nat. Hist.*, Vol. II, pt. 1, No. 2, pl. 1, fig. 3.

Pedicle Opening. — The deltoidal plates of very young individuals first appear as narrow pieces on either border of the delthyrium and begin to coalesce along the median line where the specimen is about 3 mm. in length. At this same stage the pedicle begins to encroach upon the ventral beak. In adults the pedicle opening is rather large and circular, and there is a cylindrical tube extending from the opening forward into the umbonal cavity. The deltoidal plates are strong, convex and united along the median line. The dorsal beak is somewhat rostrate and extends into the anterior end of the delthyrium.

Muscle Scars. — The scars of the muscles are not deeply impressed. In the dorsal valve there are two diverging raised lines which extend about one third the distance to the front. Between them is a longer median septum which bifurcates at its anterior end. Between the diverging lines of the posterior set are two oval adductor scars which, in some specimens, are fairly plain. Outside of them are two larger anterior adductor muscle scars whose limits are faint.

In the ventral valve under the umbo there is a large triangular pedicle muscle scar. The adductor scars are narrow and elongate. The limits of the diductors could not be made out.

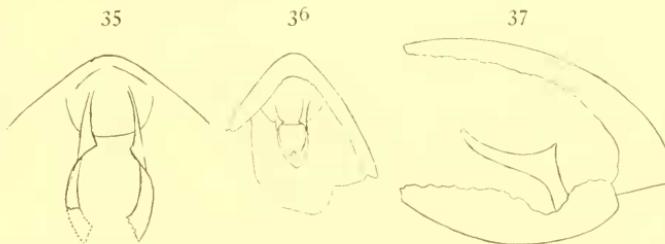


FIG. 35. *Eunella linckheni* Hall; part of the loop of an adult specimen. $\times 8$.

FIG. 36. Centronelliform stage of the loop. $\times 8$.

FIG. 37. Side view of specimen shown in Fig. 36; shell broken away to show the loop. $\times 16$.

Brachidium. — The smallest specimen retaining the brachidium, and the only one in which the loop is complete, is about 4 mm. in length. The loop extends about half the distance to the front of the valve. The primary lamellæ run sharply upward and forward and the anterior lamellæ run about parallel to the floor of the valve, meeting in the front in an acute angle. As the two lamellæ approach each other they become wider and, when they join, there is also a point directed backward. This is evidently an immature loop, and differs much from that of the adult. It agrees with the centronelliform stage

as described by Beecher and Schuchert. (*Proceedings Biol. Soc. Wash.*, Vol. VIII, p. 73, pl. X, fig. 1.) This is the second genus of brachiopods in which this stage of the loop has been observed and its presence serves to confirm the view expressed in the paper referred to, that the *Centronella* form of loop is a primitive loop for this superfamily of brachiopods. It differs slightly from the loop of *Dialasma turgida* (*Loc. cit.*, pl. X, fig. 1) in that the lamellæ are narrower and the angle in front is not so acuminate.

Cyrtina hamiltonensis Hall. (Plate V, Row 6.)

Hall, Pal. N. Y., 1867, p. 268, pl. 27, figs. 1-4, pl. 44, figs. 26-33, 38-52.

Of this species there are about one hundred specimens in the collection, most of them immature individuals. The smallest shell is .53 mm. long and the width is the same. The largest is 9.13 mm. long and 13.33 mm. wide.

Nepionic Shell. — The smallest individual in the collection represents the species in the nepionic stage.



FIG. 38. *Cyrtina hamiltonensis* Hall; outline of the smallest specimen. $\times 28$.

FIG. 39. A larger specimen; profile. $\times 16$.

FIG. 40. The same; outline. $\times 16$.

FIG. 41. A slightly older individual, showing the rapid change in the relative convexity of the valves. $\times 16$.

the pedicle opening. Both valves are convex, the ventral only a trifle more so than the dorsal. No trace of the fold or sinus appears at this stage.

Changes During Development.

In Outline. — Specimens less than 1 mm. in length are usually but little wider than long. The index varies in neanic stages from 1.33 to 1.50 and in the adult stages from 1.45 to 1.75. The width at the hinge is, in all stages, usually a little less than the greatest width below, sometimes equals, but very rarely exceeds it.

Convexity of Valves. — Specimens in the nepionic and earliest neanic stages, with a shell .75 mm. or less in length have the valves

of nearly equal convexity. The ventral area is curved and inclined backward so that the ventral beak projects beyond the dorsal. In stages but little later, when the shell is slightly over 1 mm. in length, the ventral valve is four or five times as deep as the dorsal. At this time the ventral area is high, and curved, and the beak is a little anterior to the hinge line. In more mature shells the area on the ventral valve may become flat and inclined forward or may be curved and inclined backward, as in the neionic stage. In some individuals this curvature and backward tilting of the area become very strong. It seems to be a senile character as specimens in which it is very pronounced show several strong growth lines.

The height of the cardinal area is variable, but in proportion to the width at the hinge, it is decidedly less in very young stages than in older ones. In two specimens less than 1 mm. on the hinge the height was .26 of the hinge width. In a specimen 1.02×1.3 mm. this index was .36; in one 3.33×5.13 mm., it was .58; and in-



FIGS. 42-44. *Cyrtina hamiltonensis* Hall. Anterior, cardinal and dorsal views of a specimen in the stage before the inception of plications. $\times 16$.

FIG. 45. The same species. Section through the ventral valve of an adult, showing medium septum and the peculiar double tube at the bottom of the groove formed by the dental lamellae. $\times 8$.

creased to .69 in an individual 4.43×6.86 . This rate of increase does not hold for all specimens, however, and the curvature of the area prevents the accurate determination of this index on the majority of cases. In the largest specimen in the collection which has a flat area, the index is .55. The specimen is 7×12.4 mm. and the area is 6.8 mm. high.

Plications. — When the shell has reached a length of from .45 to .60 mm. a sinus is formed in the ventral valve and very soon after its initiation a fold is produced in the opposite shell. This stage, in which there is no other ornamentation than the fold and sinus, continues for some time. The largest specimen showing this state is 1.5 mm. long and 2.26 mm. wide. Shells at this period are almost globular and are difficult to tell from the young of *Ambocelia umbonata*, unless carefully examined.

The plications are introduced in pairs on the lateral margins, each pair coming in outside the older ones. The plications are added on both valves at practically the same time, so that not counting as plications the two ridges which bound the sinus in the ventral valve, nor the fold on the dorsal, there are always the same number on both valves. On a specimen 2.43 mm. long and 3.40 mm. wide, there are two plications on each valve. On one 3.13 mm. long there are 6; on one 3.33 mm. long there are 8; at 4.76 mm. long there are 10; at 7 mm., 12; and at 9.13 mm., 16.

In adults there is a depressed line along the middle of the fold, giving it a flattened and, sometimes, divided appearance.

Pedicle Opening. — In the neionic stage the pedicle opening is large and oval and is shared by both valves. In early neanic stages it becomes restricted to the ventral valve, in which there is a narrow triangular delthyrium bounded by dental lamellæ which unite with a median septum a short distance in front of the area. This spondylum is visible at the beak of a specimen less than 1 mm. in length and continues to grow throughout life. In adult specimens it reaches down about two thirds of the distance from the apex to the cardinal line. The median septum projects behind the point where the dental lamellæ are joined to it and from its posterior edge two thin partitions run diagonally forward and join the dental lamellæ, thus forming a V-shaped ridge in the bottom of the spondylum. There are two triangular cavities between these partitions, the dental lamellæ and the median septum, but they do not appear to have an opening on the external surface of the shell at any stage (Fig. 45).

In the neanic stage at which there are two plications on each valve, *i. e.*, when the shell is from 1.6 to 2.4 mm. long, narrow deltoidal plates are formed, which, at a later stage, when the shell is from 3.0 to 3.5 mm. in length, coalesce along the median line and continue to cover the lower part of the delthyrium throughout life. A pedicle opening is left at the apex.

Comparison with Specimens from Other Localities.

The mature specimens from Canandaigua Lake are from 6 to 9 mm. in length and 8 to 12 mm. in width, and bear from 8 to 12 plications. The hinge width is generally less than the greatest width, and the ventral area is inclined either backward or forward. For comparison with this material, specimens from York, Livingston Co., and Eighteen

Mile Creek, N. Y., Thedford, Ontario, and Alpena, Michigan, were selected from the rich collections of the Peabody Museum.

With the other New York specimens the present material agrees in general size and in number of plications. The largest of the specimens from York measured 7.4×12 mm. and had 10 plications. The height of the area of this specimen was .62 of the width of the hinge. All the specimens from this locality had either 8 or 10 plications. The hinge width was equal to the width below, shorter, or, in one case, slightly larger. A dorsal beak showed two stages of growth, the smaller of which had only the fold developed and the larger had four plications. In the smallest specimen, 4×6.2 mm., the deltidial plates had coalesced over the lower third of the delthyrium.

The Eighteen Mile Creek specimens showed much the same characters. The largest specimen was 7×10 mm. and had 8 plications. The smallest was 3.8×5.4 mm. and had four plications. On this specimen the deltidial plates were still separated. The width at the hinge is always equal to, or less than, that below.

About 200 well-preserved specimens from Thedford were examined. Most of them are larger than the average of those from New York.¹ The smallest specimen is 6.4×10 mm. and the largest is 11×22.4 mm., with 22 plications. The majority have from 12 to 18 plications. In the smallest specimens the width of the hinge is about equal to the greatest width below. In the larger ones it is almost invariably greater, and the shell is frequently auriculate at the cardinal extremities.

The areas of all the shells are inclined backwards and frequently strongly curved and distorted. In no case was there any filling of the pedicle opening by testaceous matter, even in the oldest shells.

The shells from Alpena, Mich., resemble the Ontario specimens more than they do those from New York State. They are large, 7×12 to 9.6×15.4 mm., and have from 10 to 16 plications. The hinge width always equals or exceeds the width below, but the specimens in the collection are not auriculate.

¹ Hall mentions this in Vol. IV, Pal. N. Y., p. 867, p. 269. He says: "The specimens of the Hamilton group of New York are usually small, measuring about half an inch in length and breadth; the largest one seen by me being a little more than eleven-sixteenths of an inch in width and about eleven-sixteenths in length from the apex to front of valve. In some Canadian specimens the length and width are about seven-eighths of an inch."

Comparison with Other Species.

The earliest known species of *Cyrtina* in American faunas is the *C. pyramidalis* Hall, a rare shell from the Niagara. Owing to the very limited number of specimens, little is known of its variation, but the figures in Vol. II, Pal. N. Y., show a shell which is, in some respects, more primitive than *C. hamiltonensis*. It is smaller and there are fewer plications. The cardinal area is high, as compared with the width at the hinge, flat, and has a narrow delthyrium with convex deltoidal plates. The length is 7.8 mm., the width at the hinge, which is the greatest width of the shell, is 11 mm., and the height of the cardinal area is 7 mm. There are 10 plications.

The next species in point of time, is *C. dalmani* Hall from the Lower Helderberg. This is an extremely variable species, but the average specimen is smaller and has fewer plications than *C. hamiltonensis*. The smallest specimen figured by Hall is 2.4 by 4.3 mm. and has four plications. The largest is 8 \times 16 and has 14 plications. An average specimen is 6 \times 10.5 mm. with 8 plications. This species shows more advanced characters than *C. pyramidalis* in having the mesial lobe flat, sometimes with a depressed line, and in the greater number of plications.

Cyrtina biplicata Hall from the Schoharie grit and *C. crassa* Hall from the Corniferous, are two large shells which retain neanic characters. *C. biplicata* does not develop any plications except those which bound the sinus, but has the surface covered with fine striae. *C. crassa* has only four plications on each side of the fold.

C. hamiltonensis, as it occurs in the Schoharie, is small, about 8 \times 11 mm. and has only six plications.

***Spirifer mucronatus* Conrad. (Plate VI, Rows 1 and 2.)**

Hall, Pal. N. Y., IV, 1867, p. 216, pl. 34, figs. 1 to 32.

There are about 300 specimens of this species in this collection from which a series can be chosen which represents the shell in all stages of growth between a size of 1.06 by 1.48 mm. and 14.8 by 52 mm.

Protogulum.—On the beak of a well preserved dorsal valve 2 mm. in length was the impression of the initial shell. It was circular, somewhat convex, with a curved hinge. The diameter was 11 mm. Around it were two concentric growth lines marking later growth stages. One indicated a shell .25 mm. long and .27 mm. wide and the other a shell .27 by .32 mm.

Nepionic Shell. — In the nepionic stage, the shell is oval in outline and broader than long. Both valves are convex, the ventral a little deeper. The hinge width is less than the greatest width below. The surface of the shell is smooth with no fold, sinus or plications. On one specimen the nepionic shell is .45 mm. long and .73 mm. wide. On another it is .38 mm. long and on a third it is .60 mm. in length.

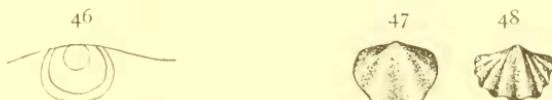


FIG. 46. *Spirifer mucronatus* Conrad; outline of protegulum and shell in nepionic stage; taken from a dorsal valve. $\times 28$.

FIG. 47. *Spirifer mucronatus* Conrad. A ventral valve showing the shell in the stage in which there are only two plications beside the ridges bounding the sinus. $\times 3$.

FIG. 48. The same species. Ventral valve at the stage when there are six plications beside those bounding the sinus. $\times 2$.

Neanic Stages. — In the earliest neanic stages a sinus is developed in the ventral valve, bounded by two strong ridges which are the first plications. Following this, a fold is formed in the dorsal valve and plications are added on the margins in pairs, each pair coming in outside the older ones. The later plications added do not reach to the beaks.

The smallest shell in the series, a ventral valve 1.06 mm. long and 1.48 mm. wide, has the median sinus, the two plications bounding it, and two very short lateral plications. The delthyrium is wide and without deltidial plates.

The ventral valve, in early neanic stages, is about twice as deep as the dorsal.

When the shell is about 2 mm. in length an impressed line appears on the fold of the dorsal valve and, soon after, a faint fold or plication appears in the ventral sinus and grows constantly stronger throughout life.

In an early neanic stage the hinge width becomes the greatest width of the shell and the cardinal extremities soon become acuminate. Specimens up to five or six mm. in width do not have the strong mucronations but nearly all adolescent shells above that size have them. In one series measured the index increased constantly from 1.30 in a shell 1.73 mm. in length to 3.5 in an adult 14.8 mm. in length. This last shell did not have the mucronate cardinal extremities.

Adult.—In the adult state the valves are about equally convex and bear from 10 to 26 pairs of plications. The cardinal extremities are acute, but are not prolonged into the spiniform extremities as in the neanic stages. The shells are of a wide type, with a high index, 2.25 to 3.00. The front is regularly curved. The fold is broad and marked by a deeply impressed line and there is a distinct plication in the sinus. The surface is covered with concentric lamellae of growth which, in old specimens, are so prolonged on the plications as to give the surface a spinose character. Three individuals, or one per cent. of the whole, show senile characters in the thickening of the shell, the spinose surface, and great number of growth lines toward the front.

Comparison with the Same Species from Other Localities.

Specimens from Cherry Valley, Otsego Co., have about the same form as those from the present material. The cardinal extremities are acute, but not far extended, and the front is regularly curved. The specimens are large; 13 to 17 mm. long and 40 to 58 mm. wide, and have a relatively small number of plications, 24 to 40. The index varies from 2.35 to 4.46. The specimens do not show the depressed line in the fold or the plications in the ventral sinus. Specimens from Worcester, Otsego Co., from the collection of Miss Grace Goodenough, show two forms, one short, wide form like the specimens from Canandaigua Lake, and a long form with a very low index and rather blunt cardinal extremities. Specimens of both types show the depressed line in the dorsal fold and most of them have the plications in the sinus of the ventral valve. A small specimen of the short type is 6 mm. long and 29 mm. wide and has 32 plications. A large specimen of the same type is 19 by 66 mm. with 50 plications. The index varies from 2.81 to 4.83 among individuals of this form.

A large specimen of long form is 28 mm. long and 35 mm. wide, and has 40 plications, while a small individual is 9 by 12.5 mm. with 26 plications. The index in this type of shell varies from 1.25 to 1.60.

The specimens from East Bethany belong to the same type as those from the silicified material and have about the same range in size and in number of plications. The index varies from 2.00 to 3.69; the plications from 14 to 40; the length from 7.5 to 19; and the width from 15 to 60 mm. All of the 62 specimens from this locality have

the depressed line in the dorsal fold, but only 25, 40 per cent., have a plication or raised line in the bottom of the sinus. Four specimens show senile characters.

From Eighteen Mile Creek there are three well-marked varieties. One, the most common, is rather long, nearly semicircular in form, and has very much prolonged cardinal extremities, and the front regularly curved. The third variety is long and comparatively narrow, with rounded cardinal extremities. This form is rather rare and is produced by the stopping of growth along the hinge at the end of the neanic or in early ephobic stages. In the neanic stages the shell is acuminate at the cardinal extremities.

The index of shells of the first form, when they are so preserved as to retain their cardinal extremities, is very high. One specimen, 11 mm. long, has an index of 4.45. With the spiniform extremities the width is 49 mm. Without them, it is 20 mm. As most of the specimens had at least a part of each cardinal extremity broken off, the index in this variety varies from 1.80 to 3.00 in ordinary specimens. The plications number from 16 to 44, those shells with the highest index having the greatest number of plications.

The second variety includes shells with an index of 2.00 to 3.00, 7 to 13 mm. long and 13 to 39 mm. wide. They carry from 16 to 32 plications. This is the Canandaigua Lake type, but the specimens are rather under normal size.

The index in the third variety is from 1.40 to 1.94 and the number of plications from 18 to 30. Only six specimens of this variety were contained in a collection of about 300 shells. Four of the six bore 22 plications each. The largest of these shells is 20.4 by 31 mm., and the smallest 15 by 21 mm. From the growth varices preserved on the shell it can be seen that these shells (in their neanic stages) passed through forms like varieties one and two.

Of the 164 specimens of all three varieties examined, all but six had a depressed line in the fold of the dorsal valve, while only 30, 18 per cent. had the plication in the sinus of the ventral valve. Only six specimens were found which showed strong senile characteristics.

According to Grabau, *S. mucronatus* is common below the Encrinial limestone, but rare above it in the Eighteen Mile Creek section. He mentions a specimen, probably of the first variety, which was 15 mm. long and 100 mm. wide.

From Thedford, Ont., there are in the collections of the Peabody Museum a great number of well-preserved specimens belonging to this species. They can be separated into three well-marked varieties, but there is a great amount of variation within the limits of these varieties.

First and least common is the form very much like the specimens from Canandaigua Lake. It is short but wide. The front is regularly curved and the cardinal extremities, while acute, are not extended into spiniform projections. The dorsal fold has a depressed median line, but there is no corresponding plication in the ventral sinus. The index is from 2.16 to 3.00; length, 6 to 17 mm.; width, 14 to 41 mm.; plications, 18 to 40. This is probably the shell given the varietal name *arkansis* by Shimer and Grabau,¹ but none of the specimens in the Yale collection show the plication in the sinus of the ventral valve.

In the neanic stages, as shown by the growth lines, this variety is short and rather strongly mucronate.

A second variety is the long form, which is straight in front and with the sides straight or slightly curved. The cardinal angles are acute and the extremities somewhat prolonged in well preserved specimens. This type is fairly common. The index is low, 1.60 to 2.00. The length from 15 to 20 mm., the width from 25 to 35 mm., and there are 18 to 30 plications, usually about 22 or 24 on each valve.

The third and most common form is nearly semicircular in outline, with the cardinal extremities somewhat produced. The shell has a tendency to become somewhat robust, especially in the later stages. The index varies from 1.85 to 2.92. The more common range is from 2.05 to 2.30. There are usually from 22 to 30 plications, though there may be as few as 14 on small individuals and as many as 40 on large ones. In the adult, some have the depressed line in the fold of the dorsal valve and some do not. This is the variety *thedfordensis* of Shimer and Grabau (*loc. cit.*).

The index here given is too low, as the cardinal extremities are so worn and broken in the adult that it is difficult to say exactly what the mature form was. But, judging from the growth lines, it is probable that the extremities were acuminate, not, however, nearly so ex-

¹ "The Hamilton group of Thedford, Ont., Shimer and Grabau." Bull. Geol. Soc. Am., Vol. 13, pp. 149-186, June, 1902.

tended as some of the Eighteen Mile Creek specimens. In the earlier stages the shells were more mucronate. The neanic stages of all three varieties seem to have been about the same, as all show the short shell, the extended cardinal extremities and the depressed line in the dorsal fold. In the first variety, the later neanic and adult growth has been transverse, while in the other two forms it has been longitudinal as well. All these varieties contain specimens which present senile conditions. Out of 680 specimens examined 20 per cent. (136 specimens) showed senile characters. These characters are most commonly expressed at the Thedford locality by strong varices of growth near the anterior margin of the shell which increase the depth of the valves and produce a broad flat anterior face in place of the sharp junction of the valves in the normal shell. The shells also become thickened, and lateral growth stops.

Of 400 adult specimens, 182 showed a trace of the depressed line in the fold of the dorsal valve, while the remainder, 55 per cent., did not. Of those which showed the depressed line, many had only the faintest trace of it, while others, 7 per cent. of the whole, had a well marked sinus along the median line of the fold. To this class belong all of variety one, the short wide form, and a few of the third variety. None of the specimens show the plication in the sinus of the ventral valve.

Delthyris consobrinus d'Orbigny.

Hall, Pal. N. Y., IV, 1867, pl. 35, figs. 15-33.

There are about 50 specimens in the collection belonging to this species. They are all small for the species. The largest is 9.4 mm. long and 17.4 mm. wide, and the smallest is 1.28 mm. by 1.38 mm. The specimen figured by Hall as an individual of average size is 15 mm. long and 25 mm. wide, while the largest figured by him is 17 \times 32 mm. and the smallest 6 \times 10.6 mm.

The developmental changes are about the same as in *Spirifer mucronatus*, the only striking difference being that the valves are subequally convex in the early neanic stages and the ventral valve becomes much deeper than the dorsal in the mature shell, while in *S. mucronatus* the reverse is the case.

Nepionic Stage.—In the nepionic stage the shell is biconvex and oval in outline. It is broader than long, the hinge width less than the width below. The surface is smooth. The length is from .35 to .50 mm. In one specimen the dimensions are .41 \times .53 mm.

Neanic Stages. — As in *S. mucronatus* and *Cyrtina hamiltonensis* the first change from the neionic shell is the formation of a ventral sinus, which is bounded by two strong ridges. This is followed by the formation of a fold and two plications on the dorsal valve. Plications are then introduced, in pairs, on the lateral margins. With the appearance

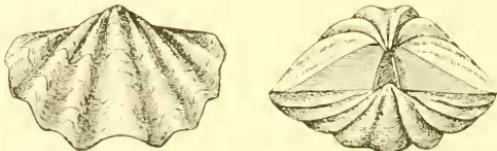


FIG. 49. *Spirifer crispus* (Hisinger). Dorsal and cardinal views of a specimen from Waldron, Ind. $\times 2$. Compare with Fig. 48.

of the first pair of plications the hinge width becomes greater than the width below and, during the later stages, the shells are mucronate. The index varies from 1.13 in a shell .44 mm. long with 4 plications, to 2.30 in a shell 6 mm. long and bearing 12 plications. The adults have from 10 to 14 strong plications. Unfortunately, the deltidial plates are so completely broken away in all the specimens as to make it impossible to learn anything of their manner of development.

It is interesting to note that these transversely elongated Devonian Spirifers pass through, in their early neanic stages, forms which correspond to the adult condition of certain Niagara species. The adult

of *S. crispus*, with a fold and eight plications on the dorsal valve, the ventral valve deeper than the dorsal, and a hinge width nearly equal to the width below, corresponds very closely in these particulars, and in its index, with a specimen of *S. mucronatus* about 2 mm. long and,

FIG. 50. The same species. Dorsal and cardinal views of a specimen from Gotland. $\times 4$.

Figs. 49 and 50 are from specimens in the Baron de Bayet collection, now the property of the Carnegie Museum.

except in the number of plications, with a specimen of *D. consobrinus* one mm. long (Figs. 49, 50).

Spirifer radiatus, with no plications, the width only one seventh greater than the length, and the width at the hinge less than the width below, corresponds to a still earlier stage in the development of these species.



SUMMARY.

The foregoing descriptions show that the general deductions which have been previously drawn as to the character of the nepionic shell, the development of the pedicle tube and the deltidial plates, and the acquirement of surface characters, hold good in the families here studied for the first time. Other general facts will be noted under the families.

Centronellidae. — The shape of *Trigeria lepida* in the nepionic stage is almost exactly that of adult *Centronella*, and thus another bit of evidence is added to that afforded by the loop, showing its relation to the Centronellidae rather than to the Terebratulidae. Going back to the very earliest stage, before the development of the dorsal sinus, the shell has characters common to the superfamily, that is, a biconvex shell with the ventral beak extended beyond that of the dorsal valve.

Terebratulidae. — *Eunella*, in its early stages, is a rather simple, generalized type of shell, not differing greatly from the very youngest stage of *Trigeria*, but the development of its loop shows progress beyond the centronelliform stage. The position of the first three punctæ, which is the same as that in the recent genus *Teretrabulina*, is interesting.

Terebratellidae. — The evidence that *Tropidoleptus* belongs to this family has not been strengthened or diminished by the present studies. It still rests on the form of the loop as described by Hall, and later verified by Hall and Clarke. The development is similar to that of the Strophomenidae, and the articulation is like that in *Chonetes*. No deltidial plates are developed, and the pedicle is probably functional throughout life. The cardinal process is very large, and of a peculiar type, quite different from that of any of the Strophomenidae.

Spiriferidae. — The marked difference in shape and relative convexity of valves of *Cyrtina* in the early neanic stage, from *Spirifer* and *Delthyris* in the same stage, together with the geological range, would seem to indicate that, while both may be derived from the same ancestral stock, *Cyrtina* is not a modified *Spirifer*. *Delthyris*, *Spirifer*, *Ambocerata* and *Cyrtina* all start out with an equivalve nepionic shell and a pedicle opening shared by both valves. But with the first changes in later nepionic and early neanic stages, when the fold and sinus appear, *Cyrtina* and *Ambocerata* become strongly inequivale, while in *Spirifer* and *Delthyris* the valves retain for a short time their equality of convexity. In other words, the generic habit is assumed immediately after leaving the form that is common to all the members of the superfamily, and *Cyrtina* passes through no *Spirifer*-like stage.

Spirifer and *Delthyris* are so exactly alike in their external form in the youngest neanic stages that it is impossible to separate them.

Strophomenidae. — The biconvex nepionic shells of *Stropheodonta*, with a median dorsal fold and ventral sinus (which may or may not be present) and the similar nepionic shells of *Chonetes* indicate a possible common origin in some shell whose external form resembled *Triplecia*, though probably not in that genus, which thus far has not been found below the Calciferous, while *Rafinesquina*, which would seem to be the immediate ancestor of *Stropheodonta*, extends into the Chazy and probably lower, without any marked change in form. The early neanic stages of *Stropheodonta*, before the appearance of the crenulations on the hinge margin, are very similar to the adult *Rafinesquina*.

An interesting feature in the development of *Stropheodonta* is the marked mucronation of the cardinal extremities of the adolescent specimens. This mucronation disappears to a greater or less extent in the older stages. This same thing is noticed in *Spirifer*, and there many of the adults retain the mucronate forms, but they are only a phase in the life of the genus. In the ontogeny the outline changes from rounded forms in the nepionic and early neanic stages, though a mucronate form in the later neanic, and back to a rounded form in the adult or senile condition. The same thing occurs in the phylogeny of *Spirifer*, at least, for there are Niagara species with rounded cardinal extremities, then a great development of the mucronate types in the Lower and Middle Devonian, and a return to the rounded forms in the Carboniferous. A similar change is seen in *Platyostrophia*.

The difference between the varieties *pectenacea* and *arctistriatus* of *Orthothetes chemungensis* is a good example of the effect of acceleration in the development of certain characters. The steps in the development of the two are exactly the same, but because the striae are introduced at an earlier stage on one than on the other, the shells differ greatly in appearance.

Productidae. — The facts in the development of *Chonetes* do not seem to support the idea put forward by Hall and Clarke that *Chonetes* might be descended from *Plectambonites*, a shell which in many respects much resembles *Chonetes*. The early neanic stages have an outline which is much the same as that of *Rafinesquina* and *Stropheodonta*. The resemblance of the nepionic shell to *Triplecia* has already been referred to, and this, with the other characters, relates the shell to the Strophomenidae. It is clearly a transition form between the latter family and the Productidae.

PART II. A STUDY OF A HAMILTON FAUNULE FROM
CANANDAIGUA LAKE, N. Y.

INTRODUCTION.

The material on which the preceding studies were based, was, as is stated in the introduction to part I, obtained from a clayey limestone by etching with hydrochloric acid. The outcrop from which the blocks were taken is in a ravine on the west side of Canandaigua Lake, New York, where the silicified fossils occur in several layers, but all within the seventy-five feet above the "Encinal" limestone of that region.

Sixty-five pounds of the limestone, when treated with acid, yielded about 15,000 shells which were sufficiently perfect to be saved for making up collections, and there was fully as much fragmentary material. In most cases the two valves of the shells are separated, but even taking that fact into consideration, the material must represent the remains of at least 10,000 individuals. From the vast number of the shells, it is evident that they could not have lived contemporaneously in the small space which contains their remains, but the rock must represent the accumulated shells of many years.

As the method used in obtaining the material from the matrix eliminates all the collector's personal equation, all the minute specimens are detected, and all individuals of each species saved. Thus the collection gives a very accurate idea of the fauna existing in the region at the time the rock was being deposited. It cannot, however, be taken as absolutely accurate, as there probably existed species which were not preserved and it is also possible that a larger quantity of the rock might have afforded a greater variety of forms.

The object of this part of the paper is to study this faunule in comparison with the other faunas of the New York-Ontario province, and to give an annotated faunal list.

Conditions of Sedimentation.

The rock is fine grained and contains much very fine clay. In some cases this clay is evenly distributed throughout the layer and is cemented by the lime. In that case the action of the acid is free and as a result the fossils are easily separated from the residue of fine clay by washing. Other layers have an inch or more of almost pure clay

at the top and bottom, and such layers require constant scrubbing and breaking to allow the acid to act. The fossils seem equally well silicified in both, but are not obtained in perfect condition from the latter owing to the mechanical difficulties. The lithologic character of the rock indicates rather shallow water and a sufficient distance from the shore line to prevent a mixture of sand or gravel. The fossils themselves show that their habitat was free from any violent wave action or strong currents. This is indicated both by the state of preservation, which is remarkably fine, and the presence of large numbers of species and individuals of Bryozoa. Large fronds of the delicate species like those of the Fenestellidae are often found and such delicate spines as those of *Chonetes* and *Strophalosia* are beautifully preserved.

With the exception of the phosphatic linguloid shells and a few of the pelecypods, all kinds of shells are well silicified and by this method of collecting practically everything in the rock is preserved. This accounts for the large number of species found, and for the great number of individuals of species usually called rare. *Pholidops hamiltonensis*, usually not considered abundant, is represented by over 1,500 specimens in the present collection, being second on the list of most common species. By far the most common one is *Chonetes scitulus*, of which about 3,500 specimens have been picked out. Another feature is the abundance of ostracods, of which there are above 15 species, 11 of which have been identified so far.

New species, with the exception of a new *Chonetes*, are confined to rare genera, and will not be described at present.

LIST OF SPECIES.

Anthozoa-Actinozoa :

- | | |
|---|----------------------------------|
| <i>Heliophyllum halli</i> , R. ¹ | <i>Ceratopora dichotoma</i> , c. |
| <i>Michelinia stylopora</i> , r. | <i>Ceratopora jacksoni</i> , c. |
| <i>Aulopora scrpens</i> , c. | |

Vermes :

- | | |
|------------------------------------|----------------------------------|
| <i>Spirorbis angulatus</i> , R. | <i>Cornulites</i> n. s., r. |
| <i>S. spinulifera</i> , a. | <i>Autodetus lindströmi</i> , c. |
| <i>Cornulites hamiltoniae</i> , c. | <i>Autodetus</i> n. s., R. |

¹ According to the usual custom the abbreviations *R*, *r*, *c*, and *a*, are used here. *R* signifies that the species is very rare; *r*, rare; *c*, common; *a*, abundant.

Bryozoa :

Ascodictyum stellatum, c.
Pinacotrypa plana, c.
Monotrypa fructicosa, c.
Monotrypa, sp. und. c.
Fenestella emaciata, c.
Semiscoecinum striatum, R.
Isotrypa, sp. und. R.
Hemitrypa cribosa? R.
Polypora fistulifora, r.

Brachiopoda :

Lingula, sp.
Camarotoechia congregata, R.
C. horsfordi, R.
C. sappho, R.
Trigeria lepida, r.
Eunella linkleni, c.
Tropidoleptus carinatus, a.
Atrypa reticularis, w.
Cyrtina hamiltonensis, c.
Spirifer mucronatus, a.
S. audaculus, r.
S. granulosus, r.
Delthyris consobrinus, c.
D. sculptis, r.
Reticularia fimbriata, r.
Ambocelia umbonata, r.
Nucleospira concinna, r.
Athyris spiriferoides, r.
Pholidops oblates, c.
P. hamiltonensis, a.

Pelecypoda :

Nuculites oblongatus, R.
N. triquetus, R.
Nucula corbuliformis, R.
Paleoneilo constricta, r.
Conocardium eboraccum, R.
Actinopteria decussata, R.

P. multiplex, c.
Rhombopora tortalinea, r.
Streblotrypa hamiltonensis, R.
Ptilodictya plumea, r.
Cystodicta incisurata, a.
Teniopora exigua, c.
Acrogenia prolifera, r.
Lichenalia stellata, c.
Paleschara reticulata, R.

Crania crenistriata, r.
Craniella hamiltoniae, c.
Strophadonta concava, R.
S. demissa, r.
S. inaequistriata, c.
S. junia, R.
S. perplana, c.
Pholidostrophia iowaeensis, c.
Orthothetes chemungensis, c.
O. chemungensis arctistriatus, c.
O. bellulus, c.
Chonetes coronatus, c.
C. mucronatus, c.
C. scitulus, a.
C. robustus, c.
Strophalosia truncata, c.
Productella spinulicosta, r.
Rhipidomella penelope, r.
R. vanuxemi, c.

Pterineopecten intermedius, R.
P. hermes, R.
P. regularis, r.
P. conspectus, R.
Lyriopecten orbiculatus? R.
Modiomorpha alata, R.

- | | |
|----------------------------------|--|
| <i>Aviculopecten exacutus</i> r. | <i>Cypricardella bellistriata</i> , r. |
| <i>A. princeps</i> , c. | <i>Cypricardinia indentata</i> , R. |
| <i>A. seabridus</i> , r. | <i>Nyassa arguta</i> ? R. |

Gastropoda :

- | | |
|-------------------------------------|------------------------------------|
| <i>Pleurotomaria capilaria</i> , r. | <i>P. thetis</i> , R. |
| <i>Cyclonema hamiltonensis</i> ? R. | <i>Diaphorostoma lineatum</i> , c. |
| <i>Bellerophon leda</i> , r. | <i>Loxonema delphicola</i> , r. |
| <i>Platyeras bucculentum</i> , r. | <i>Hyolithes acilis</i> , r. |
| <i>P. carinatum</i> , r. | <i>Tentaculites bellulus</i> , a. |
| <i>P. symmetricum</i> , c. | <i>Styliola</i> , sp. und. R. |

Cephalopoda :

- Orthoceras*, sp. und. R.

Crustacea :

- | | |
|--------------------------------------|---------------------------------|
| <i>Primetopsis punctilifera</i> ? R. | <i>Beyrichia kolmodini</i> , c. |
| <i>Kirkhyia parallela</i> , r. | <i>Haliella retifera</i> , r. |
| <i>Strepula sigmoidalis</i> , c. | <i>Moorea bicornuta</i> , R. |
| <i>Isochilina lineata</i> R. | <i>Proetus rowi</i> , r. |
| <i>I. fabacea</i> , R. | <i>Cyphaspis ornatus</i> , R. |
| <i>Primita seminulum</i> r. | <i>Dipleura dekayi</i> , R. |
| <i>Octonaria stigmata</i> , r. | <i>Phacops rana</i> , c. |
| <i>Ctenobolina papillosa</i> , r. | <i>Cypræus boothi</i> , c. |

DISCUSSION.

For comparison of this faunule with the faunas of other Hamilton outcrops, the species of the Thedford, Ont., Eighteen Mile Creek, Livonia and Cayuga Lake sections were tabulated with the Canandai-gua Lake species, as were also certain of those listed in Prosser's work on the Hamilton of eastern New York. In these lists only such fossils were taken as were located by the various authors in some definite stratigraphic horizon. On tabulating the species from various sections in eastern New York, as represented by Prosser, it was found that there was quite a change in the fauna of the upper part of the Hamilton where the eastern boundary of Otsego county was passed, and for that reason the fossils of Chenango and Otsego counties are grouped together and those of Albany county put with those from Schoharie county. None of the lists from the eastern part of the state are complete and any conclusions drawn at this time are of course liable to be upset when studies are made of carefully worked sections. In

addition to Professor Prosser's lists from eastern New York, unpublished lists made by Miss Grace Goodenough from the section at Worcester, Otsego county, and by various members of the Cornell Summer School of Field Geology, from East Berne, Albany county, were incorporated in the table.

The Canandaigua Lake faunule consists of about 115 species which are divided among the classes as follows:

Crustacea.....	16
Cephalopoda.....	1
Gastropoda	8
Pteropoda	3
Pelecypoda	16
Brachiopoda	39
Bryozoa	18
Vermes	6
Anthozoa.....	5

It will at once be seen from the large number of Bryozoa and corals and the small number of pelecypods that this fauna is not closely related to the fauna of the eastern counties.

In Prosser's list from eastern New York there are 131 species which can be definitely located at a certain number of feet from the top or bottom of the Hamilton section of the region. Of this list 66, almost exactly half, are pelecypods, while only 14 per cent. of the species in our faunule belong to that class. It is well known that the more western sections contain a smaller proportion of lamellibranchs than the eastern ones, but our faunule contains less than one would expect from its locality.

The Livonia section, which is only 20 miles to the west, contains 30 per cent. of pelecypods in its list of species, and the Cayuga Lake section about 30 miles east, has 32 per cent. Of course this is a comparison of one faunule with an aggregate of faunules, but it shows that conditions were unfavorable for the development of lamellibranchs at the time these strata were deposited.

Of the 112 species identified, 26 are found in none of the other sections, and so are not useful in comparisons. These are distributed as follows: Vermes, 3; Bryozoa, 6; Brachiopoda, 2; Pelecypoda, 2; Pteropoda, 1; Crustacea, 12. These are all rare or delicate species, usually small and are not apt to be obtained in ordinary collecting from sections. Of the remaining 86 species, 55 occur in that part of the

Cayuga Lake section which lies above the Encrinial limestone, and 52 in the corresponding strata of the Livonia section. The three have 40 species in common. These facts show that our faunule was a very typical one for the region and made up principally of the common species.

There are 34 species which are common to our faunule and the Chenango to Albany counties composite fauna, while there are 60 forms common to the Eighteen Mile Creek section and this faunule. With the fauna of the Thedford section there are only 31 species in common, showing that if this is not an eastern fauna, it is not a western one, but is more nearly allied to the faunas from Eighteen Mile Creek, Livonia and Cayuga Lake.

The present faunule has no dominant species which ally it to any particular faunule of the detailed sections of Cleland or Grabau. The abundance of *Crystodicta inscisurata* suggested that this faunule might be compared with the *Stictopora* faunules of Grabau and Cleland. That faunule occurs in a one-inch bed of shale just below the Encrinial limestone at Eighteen mile Creek and in the top zone (Zone Y) of Cleland's section at Cayuga Lake. The species may be compared by classes as follows:

STICTOPORA FAUNULE.

Class.	18 Mile Creek.	Canandaigua Lake.	Cayuga Lake.
Anthozoa-Actinozoa.	1	5	8
Vermes.	—	6	—
Bryozoa.	2	18	5
Brachiopoda.	22	39	33
Pelecypoda.	5	16	26
Gastropoda.	4	11	5
Cephalopoda.	—	1	—
Crustacea.	2	16	6
Total.	36	112	83

From this table it is seen that all three faunules are rich in brachiopods and poor in cephalopods and gastropods. In the matter of pelecypods there is not a close agreement, the Cayuga Lake *Stictopora* faunule having a much greater proportion than the others. At Cayuga Lake, 31 per cent. of the number of species are lamellibranchs, while at Canandaigua Lake it is reduced to 14 per cent. and at Eighteen Mile Creek to 13 per cent. The last two agree very closely in this class as in the other mollusca. There are twenty-five species which are common to all these faunules. These are:

<i>Cystodicta incisurata</i> ,	<i>S. perplana</i> ,
<i>Tæniopora exigua</i> ,	<i>S. iowænsis</i> ,
<i>Camarotoechia horsfordi</i> ,	<i>Orthotetes chemungensis arctistriatus</i> ,
<i>Atrypa reticularis</i> ,	<i>Chonetes coronatus</i> ,
<i>Cyrtina hamiltonensis</i> ,	<i>C. scitulus</i> ,
<i>Spirifer undulatus</i> ,	<i>Productella spinulicosta</i> ,
<i>S. mucronatus</i> ,	<i>Rhipidomella vanuxemi</i> ,
<i>Ambocælia umbonata</i> ,	<i>R. penelope</i> ,
<i>Reticularia fimbriata</i> ,	<i>Cypricardinia identa</i> ,
<i>Nucleospira concinna</i> ,	<i>Diaphorostoma lineata</i> ,
<i>Athyris spiriferoides</i> ,	<i>Phacops rana</i> ,
<i>Craniella hamiltoniae</i> ,	<i>Dalmanites boothi</i> .
<i>Strophodonta inaequistrigata</i> .	

All of these species are common in any Hamilton section and range from top to bottom. A comparison of almost any three large faunules would show a good part of this list in common, so that it is hardly safe to correlate the zones on such evidence. The abundance of *Cystodicta* in all these may be explained by local conditions which favored the development of large numbers of colonies.

The twelve species which are most common at Canandaigua Lake in this faunule are as follows, their relative abundance being in the order named:

<i>Chonetes scitulus</i> ,	<i>Chonetes mucronatus</i> ,
<i>Pholidops hamiltoniae</i> ,	<i>Chonetes coronatus</i> ,
<i>Tropidoleptus carinatus</i> ,	<i>Orthothetes chemungensis arctistriatus</i> ,
<i>Spirifer mucronatus</i> ,	<i>Phacops rana</i> ,
<i>Strophodonta inaequistrigata</i> ,	<i>Tentaculites bellulus</i> .
<i>Cystodicta incisurata</i> ,	
<i>Tæniopora exigua</i>	

For a comparison with this list, the dominant range frequency lists prepared by Williams¹ from a study of the Eighteen Mile Creek and Cayuga Lake sections and the distributional frequency list for eastern New York may be taken, for although these lists do not represent exactly the most common fossils, they are a close approximation.

For a further comparison there has been prepared, following William's method, a dominant range frequency list from the Thedford section as reported by Shimer and Grabau,² and it stands as follows:

¹H. S. Williams, Bull. U. S. Geol. Survey, 210, 1903.

²"The Thedford Section," Bull. Geol. Soc. Am., vol. 13, pp. 149-186, 1902.

THEDFORD REGION. (DOMINANT RANGE FREQUENCY LIST.)

Species.	No. of Zones in Which Found.
1. <i>Spirifler mucronatus</i> ,	5
2. <i>Primitopsis punctilifera</i> ,	5
3. <i>Stropheodonta iowaensis</i> ,	5
4. <i>Leiorhynchus laura</i> ,	4
5. <i>Chonetes lepida</i> ,	3
6. <i>Stropheodonta demissa</i> ,	3
7. <i>Cyrtina hamiltonensis</i> ,	3
8. <i>Stropheodonta perplana</i> ,	3
9. <i>S. concava</i> ,	3
10. <i>Athyris fultonensis</i> ,	2
11. <i>Ceratopora intermedia</i> ,	2
12. <i>Favosites turbinata</i> .	2

Shimer and Grabau divide the section into six zones, and there is no species reported which occurs in all. Three species occur in five of the six, one in four, five in three, and there are three which occur in only two. Of the twelve, nine are brachiopods, two corals and one an ostracod, which illustrates well the difference between the faunas of the western and eastern sections. In the distributional frequency list for eastern New York there are six brachiopods, five pelecypods, one trilobite and no corals. As the list for eastern New York is a distributional and not a range list, the writer has endeavored to construct a list from Prosser's report, in the absence of a detailed section, but the result is very unsatisfactory. The attempt, however, brings out one point.

In Prosser's report, some of his sections are sufficiently long and well enough located so that the approximate distance of the various zones below the top of the formation is known. There are thirteen such zones at different localities, which are located between 1 and 150 feet below the top of the Hamilton; ten located 150 and 300 feet below the top; five located between 300 and 600 feet below the top; and two which are between 600 feet below the top of the Hamilton and the top of the Marcellus.

Then making a composite section with four zones, there can be constructed a sort of a range frequency list, which is, however, of little value, because the number of species reported below the 600 foot level is very small. This list is as follows:

DOMINANT RANGE FREQUENCY LIST FOR EASTERN NEW YORK. COMPOSITE.

Species.	No. of Zones in Which Found
1. <i>Spirifer mucronatus.</i>	4
2. <i>S. granulosus.</i>	4
3. <i>Tropidoleptus carinatus.</i>	3
4. <i>Cypriardella tenuistriatus.</i>	3
5. <i>Spirifer tullius.</i>	2
6. <i>Athyris spiriferoides.</i>	2
7. <i>Paleoneilo constricta.</i>	2
8. <i>Nuculites triquetus.</i>	2

The remarkable fact about this list is that only eight out of the 131 species reported from this region occur in more than one of these zones. That is, there are only eight species so far reported to have a range of over 450 feet, and only two that range through the whole thickness of the Hamilton in this region.

There are two species which occur in three of the zones, four that occur in only two, and the rest in only one.

Comparing the list with the distributional list as prepared by Williams it is found that the first three species on both lists are the same, though *Spirifer granulosus* and *Tropidoleptus carinatus* have changed places. *Cypriardella tenuistriatus* and *Spirifer tullius* are not in the distributional list and *Paleoneilo constricta* has changed from fifth to seventh place, while *Athyris spiriferoides* has risen from eleventh to sixth place. *Nuculites triquetus* has eighth place on both lists.

Now, comparing these lists, the various range frequency lists, with each other and with the list of the most abundant species at Canandaigua Lake, it is seen that they have only one species in common, namely, *Spirifer mucronatus*. The species most abundant in our faunule, *Chonetes scitulus* is number 6 on the Eighteen Mile Creek list, but does not occur in the others. Six of the species most common at Canandaigua Lake are not on any of the lists. *Phacops rana* is No. 2 on the Eighteen Mile Creek list and No. 5 of the Cayuga Lake list. *Chonetes mucronatus* is No. 8 on the Cayuga Lake list and *Orthothetes arctistriatus*, No. 9 on the Eighteen Mile Creek list.

Comparing the list of the most common species in this faunule with the standard fauna of dominant species as prepared by Williams for the New York-Ontario province it is found that four of our species are on that list, occupying first, second, third and eighth places re-

spectively. All the species on that list except the last, *Nucula bellistriata* occur in the faunule, thus showing that it is an aggregation of very typical Hamilton species.

ANNOTATED FAUNAL LIST.

Anthozoa-Actinozoa.

Heliophyllum halli E. & H.

Ill. Dev. Foss., pl. XXIII, 1876.

In the present collection there is only a single specimen of this coral, and that is of small size. The species is common in the upper Hamilton at Thedford and Eighteen Mile Creek, is fairly common at the same horizon at Livonia, but is found only near the base of the Cayuga Lake section, and is not reported from the eastern counties.

Michelinea stylopora Eaton.

Ill. Dev. Foss., 1876, pl. XVIII.

The specimens of this species are fairly common at Canandaigua Lake. It is abundant in certain beds in the lower Hamilton at Eighteen Mile Creek and Cayuga Lake and in some upper beds at Livonia. It has not been reported from Thedford or the eastern N. Y. localities.

Aulopora serpens Goldfuss.

Geol. Survey Mich., 1873-76, p. 81, pl. 33.

This occurs quite commonly on brachiopods in our faunule, usually on some species of *Stropheodonta*. It is rare at Thedford, Eighteen Mile Creek and Cayuga Lake.

Ceratopora dichotoma Grabau.

Proc. Bos. Soc. Nat. Hist., Vol. XXVIII, p. 418, pls. 2-4.

This species is common in our material and at Eighteen Mile Creek, but is rare at Thedford and Cayuga Lake. It is not reported from Livonia or the eastern localities.

Ceratopora jacksoni Grabau.

Proc. Bos. Soc. Nat. Hist., Vol. XXVIII, p. 415, pls. 1 and 2.

This species is about as common as the preceding one in our material. It is also common in the *Demissa* bed at Eighteen Mile Creek, but has not yet been reported from the other sections.

Vermes.

Spirorbis angulatus Hall.

15th Report N. Y. State Mus. Nat. Hist., p. 84.

This species is very rare in the present collection. It is common in the *Demissa* bed at Eighteen Mile Creek, but is not reported in the other sections under consideration.

Spirorbis spinuliferus Nich.

Pal. Prov. Ont., p. 83, 1875.

This species, which has not been reported from the other sections, is extremely abundant at Canandaigua Lake in this faunule, and seems to take the place of *S. angulatus*.

Cornulites hamiltoniae Grabau.

Bull. Buffalo Soc. Nat. Sci., Vol. VI, 1898-99, p. 150, fig. 32.

This species, which is found in the Pleurodictyon beds at Eighteen Mile Creek, is fairly common at our locality.

Cornulites sp.

With the above is another species, probably undescribed, which reaches a large size, has fewer and more irregular annulations.

Antodetus lindströmi Clarke.

Am. Geol., Vol. XIII, p. 334, figs. 1-3, 1894.

This peculiar organism is quite common. The apical scar shows that it attached itself to various supports. The only specimen which remains in its attached position is resting upon a frond of *Teniopora exigua*. Some species show a broad flat surface for attachment, as much as one half the width of the body whorl, while in others it is small, and often concave. This species also occurs rarely in the lower beds at Eighteen Mile Creek.

Antodetes sp.

With the above occurs another form of the same genus, which is sufficiently unlike *A. lindströmi* to be called by another specific name. It is rare.

Bryozoa.

Ascodictyum stellatum N. & E.

Am. Mag. Nat. Hist., Ser. 4, XIX, p. 464, pl. XIX, figs. 1-6.

This little bryozoan is very common in the material, usually occurring attached to brachiopods or bryozoans.

Pinacotrypa plana Hall.

Pal. N. Y., Vol. VI, p. 215, pl. VIII, pp. 19, 20.

This species is quite common at Canandaigua Lake. It is found rarely in the lower Hamilton at Eighteen Mile Creek, but has not been reported from the other sections.

Monotrypa fructiosa Hall.

III. Dev. Foss., pl. XXXVIII, figs. 1-5, 1876.

The bryozoan known by this name, which is given no standing by Nickles and Bassler, is very abundant in the present material. It occurs also at Eighteen Mile Creek.

Monotrypa ? sp.

With the above is another more slender species which seems to be congeneric with it. It is also common.

Fenestella emaciata Hall.

36 Ann. Rept. N. Y. State Mus. Nat. Hist., p. 68, 41 Rept. idem, pl. VIII.

This species, which is quite common in the *Demissa* bed at Eighteen Mile Creek, is common also in our material.

Reteporina striata Hall.

36 Ann. Rept. N. Y. State Mus. Nat. Hist., p. 72.

This is another species which occurs both in the *Demissa* bed at Eighteen Mile Creek and in our faunule. It is rare in both.

Isotrypa sp.

A few well preserved fronds which appear to belong to this genus occur with the other Fenestellidae.

Hemitrypa cribosa Hall.

Trans. Albany Institute, p. 177.

Specimens which appear to belong to this species occur occasionally in the material.

Polypora fistulata Hall.

36 Ann. Rept. N. Y. State Mus., p. 59.

There are a few specimens which seem to agree with the figures and descriptions of this species. It does not occur in any of the sections we are comparing our faunule with, but has been reported from Genesee and Erie Counties, N. Y. and West Williams, Ontario.

Polypora multiplex Hall.

Rept. N. Y. State Geol., 1886, p. 66.

This species is common in the upper part of the Hamilton at Livonia, and in our faunule, and occurs rarely at Cayuga Lake above the Encrinia.

Rhombopora tortalinea Hall.

Pal. N. Y., Vol. VI, p. 180, pl. LVI.

This species occurs rarely in our material.

Streblotrypa hamiltonensis Nich.

Pal. N. Y., Vol. VI, p. 191, pl. LV.

This is a common fossil at Thedford above the Encrinial. It occurs rarely in the lower part of the Eighteen Mile Creek section and is very rare at our locality. It has not been reported further east.

Ptilodictya plumosa Hall.

Pal. N. Y., Vol. VI, p. 271, pl. LXI.

Several very complete colonies of this species were found in the collection. It occurs also in the *Demissa* bed at Eighteen Mile Creek.

Cystodicta incisurata Hall.

Pal. N. Y., Vol. VI, p. 241, pl. LX.

This is one of the most common species in our faunule. It is also very common in the *Stictopora* beds at Eighteen Mile Creek and Cayuga Lake and in the upper Hamilton at Livonia.

It occurs in the eastern counties only at East Berne.

Teniopora exigua Nich.

Geol. Mag. Lon., N. S., Vol. I, p. 120.

This is also a common fossil at Canandaigua Lake and is quite common in all sections from Eighteen Mile Creek to Albany Co.

Acrogenia prolifera Hall.

Pal. N. Y., Vol. VI, p. 267, pl. LXIII.

This peculiar bryozoan is fairly common in our faunule. It is not reported from the other sections.

Lichenalia stellata Hall.

Pal. N. Y., Vol. VI, p. 195, pl. LVIII.

This species is rare in the *Demissa* bed at Eighteen Mile Creek and common in the Hamilton above the Encrinial limestone at Divonia and Canandaigua Lake.

Paleschara reticulata Hall.

Third Ann. Rept. N. Y. State Geol., p. 6.

This species occurs rarely in both the *Demissa* bed at Eighteen Mile Creek and in the faunule at Canandaigua Lake.

Brachiopoda.

Lingula sp.

A few fragments of Lingulas which could not be identified on account of their condition, were found in breaking up pieces of the rock. The *Lingula* shells were not silicified.

Camarotochia congregata Conrad.

Pal. N. Y., Vol. IV, 1867, p. 341, pl. 54.

This species is very rare, and only one or two specimens were found. The species seems to reach its greatest development toward the east as it has not been reported from Thedford, Eighteen Mile Creek or Livonia, and is rare in the Cayuga Lake section. It is abundant at certain localities in Otsego and Albany counties.

Camarotochia horsfordi Hall.

Pal. N. Y., Vol. IV, 1867, p. 339, pl. 54.

In the present material this species is very rare. It occurs rarely throughout the section of Eighteen Mile Creek, and was found in the Encrinial bed and in the *Cystodicta* zone at Cayuga Lake. It has not been reported from the eastern New York counties.

Camarotochia sappho Hall.

Pal. N. Y., Vol. IV, 1867, p. 34, pl. 54.

This is another species which occurs only in the *Cystodicta* bed and in the Encrinial at Cayuga Lake. It has been found in all sections from Thedford to the eastern counties, is common below the Encrinial limestone at Eighteen Mile Creek and abundant in the Upper Hamilton at West Berne, Albany Co. In the faunule from Canandaigua Lake it is very rare.

Trigera lepida Hall.

Pal. N. Y., VIII, 1893, p. 274, pl. 50, figs. 36-40.

This uncommon fossil, of which fifteen specimens were obtained from this material, is here much smaller than the typical specimens. The largest is 6.8 mm. long and 6 mm. wide, and has 14 striae on the brachial and 15 on the pedicle valve. The largest specimen figured by Hall is 11 mm. long and 9.5 mm. wide. According to that author an adult should have from 20 to 25 plications.

Of the sections under consideration, Thedford is the only one which has yielded specimens of this shell.

Eunella linkleni Hall.

Pal. N. Y., Vol. IV, 1867, p. 397, pl. 60, figs. 49-65.

This is another species with an eastern distribution. It is common from Canandaigua Lake to Albany Co., but has not been reported from Thedford, Eighteen Mile Creek or Livonia. The specimens from the present material do not show any unusual characters.

Tropidoleptus carinatus (Conrad).

Pal. N. Y., Vol. IV, 1867, p. 407, pl. 62, figs. 2, 3.

This species is very abundant in the faunule, but the individuals do not attain so great a size here as in some other localities. The largest specimen is 22×28 mm., while the average is somewhat below that size, about 19×24 mm., with from 17 to 21 plications. There are two varieties, one in which the plications are rounded, and another in which they are more angular, and separated by wide interspaces.

As is well known, this species is very abundant in the eastern part of New York State, is common all through the section at Cayuga Lake, common above the Encrinial at Livonia and Eighteen Mile Creek, and very rare at Thedford, Ont.

Atrypa reticularis Linnæus.

Pal. N. Y., Vol. IV, 1867, p. 316, pls. 51-53 A.

This fossil is very rare at the Canandaigua Lake locality. It is found in all the sections from Thedford to Albany Co.

Cyrtina hamiltonensis Hall.

Pal. N. Y., Vol. IV, 1867, p. 268, pl. 27, figs. 1-4, pl. 44, figs. 26-33, 38-52.

This is a species which seems to reach a higher development in the western than in the eastern sections. It is rare in eastern New York, and at Cayuga Lake, common at Canandaigua Lake, fairly common near the top of the Livonia section, common below the Encrinial at Eighteen Mile Creek and common above the limestone at Thedford.

The largest shell in the present collection is 9 mm. long and 13 mm. wide, with 16 plications. It is a little above the average size for the adults from this locality. The majority of the specimens agree well in size and other particulars with specimens from the other Western New York localities. The specimens from Thedford, Ont., the Alpena, Mich., are somewhat larger.

Spirifer mucronatus Conrad.

Pal. N. Y., Vol. IV., 1867, p. 216, pl. 34, figs. 1-32.

This species is common in this faunule, as in all the sections from Thedford to eastern New York. All the adult individuals in the collection belong to one variety. The valves are about equally convex, and the cardinal extremities acute, but not mucronate. The width is from two to three times the length. There are usually from 10 to 26 pairs of plications, depending on the size of the individual, and the

fold of the dorsal valve is always divided by a median depressed line. The largest specimen is 14.8×52 mm. This type is found also in eastern New York, East Bethany, Eighteen Mile Creek and Thedford, Ont., but in all those localities there are other varieties associated with it.

S. audaculus Conrad.

Pal. N. Y., Vol. IV., 1867, p. 227, pl. 38.

The specimens of *S. audaculus* are few, and smaller than the usual adult size of this shell. The species is rare at Thedford, but common in the other sections. It usually is most common in the upper zones east of Eighteen Mile Creek.

S. granulosus Conrad.

Pal. N. Y., Vol. IV., 1867, p. 223, pl. 36.

In the lower zones at Eighteen Mile Creek and in certain localities in the upper Hamilton of Otsego Co., this species is very common. At Livonia and Canandaigua Lake it is rare, and it is likewise uncommon in Albany and Schoharie Counties.

Delthyris consobrinus d'Orbigny.

Pal. N. Y., Vol. IV., 1867, p. 222, pl. 35.

This species showed the usual characters, but some specimens had so few plications as to approach *D. sculptis* in character. The species has not been reported either from Thedford or eastern New York. It is common in this faunule, as it is in two of the zones above the Encrinial at Eighteen Mile Creek. It was not reported from Livonia and is not common at Cayuga Lake except in a couple of zones near the top of the section.

Delthyris sculptis Hall.

Pal. N. Y., Vol. IV., 1867, p. 221, pl. 35.

Two or three well preserved specimens of this species were obtained which showed the usual strong plications. The vertical range of this species does not seem to be very great. At Thedford and Eighteen Mile Creek it is confined to the Encrinial limestone, and at Cayuga Lake it occurs in only one zone (D). At Livonia it occurs above the Encrinial, as it does at Canandaigua Lake.

Reticularia fimbriata Conrad.

Pal. N. Y., Vol. IV., 1867, p. 214, pl. 33.

This species has been found from Thedford to Otsego Co., but it is usually rare in the various localities, as it is in this faunule.

Amboceratia umbonata Conrad.

Pal. N. Y., Vol. IV, 1867, p. 259, pl. 44.

While young individuals of this species were not uncommon, only three or four adults were found, and they were all of small size. The species is common from Thedford to Albany Co.

Nucleospira concinna Hall.

Pal. N. Y., Vol. IV, p. 867, p. 279, pl. 45.

This species is rare in this faunule, rare in the upper Hamilton at Thedford and Livonia, and found all through the sections at Eighteen Mile Creek and Cayuga Lake, though it occurred in only a few zones and was rare except for a short distance below the Encrinial at Eighteen Mile Creek. It is not reported from eastern New York.

Athyris spiriferoides Eaton.

Pal. N. Y., Vol. IV, 1867, p. 285, pl. 46.

This shell common and of large size, although few of the specimens were silicified. The species is common in all sections.

Pholidops oblates Hall.

Pal. N. Y., Vol. IV, 1867, p. 414, pl. 3, fig. 10.

Of the sections here used for the comparisons, only two, Eighteen Mile Creek and Cayuga Lake, have furnished specimens of this fossil, and in both localities it is confined to the Encrinial limestone, where it is found but rarely. In the present locality it is common, over 200 specimens having been obtained.

P. hamiltoniae Hall.

Pal. N. Y., Vol. IV, 1867, p. 32, pl. 3, figs. 6-7.

This is one of the most abundant fossils in the faunule, as there are about 1,500 specimens in the collection. According to Cleland, the vertical range of this species is about the same in the Eighteen Mile Creek, Livonia and Cayuga Lake sections, and the center of abundance in the upper part of the Lower Hamilton. The largest specimen in this collection is 3.9 mm. long and 3.2 mm. wide, practically the dimensions of the largest specimen from Cayuga Lake. The shell has been found in the Upper Hamilton at Thedford, but has not yet been reported from the eastern counties.

Crania crenistriata Hall.

Pal. N. Y., Vol. IV, 1867, pl. 3, figs. 1-16.

This species is not common. The largest specimen is 12.5 mm. long and 13.5 mm. wide. The fossil is found rarely in the upper

Hamilton at Thedford, and below the Encrinial at Eighteen Mile Creek.

Craniella hamiltoniae Hall.

Pal. N. Y., Vol. IV, 1867, p. 27, pl. 3, figs. 17-23.

This species is fairly common in the material and presents the usual characters. The largest specimen is 15.2 × 19 mm. The dorsal valves show a variety of markings, varying with the shell to which they were attached. Most of them show the coarse ribbing of *Tropidoleptus* or *Spirifer*. The species does not seem to be common very often, but is found from Thedford to Otsego Co.

Stropheodonta concava Hall.

Pal. N. Y., Vol. IV, 1867, p. 96, pl. 16, figs. 1a-1h.

This species is very rare in the locality. One dorsal valve of an adult individual was found, and two or three shells of younger specimens. The species is found in all sections from Thedford to Otsego Co., but is seldom common.

S. demissa Conrad.

Pal. N. Y., Vol. IV., 1867, p. 101, pl. 17.

This species is found from Thedford to Cayuga Lake, but its vertical range in the various sections is very limited and it cannot be called a common fossil except on its western range where it is common in certain zones. At Thedford it is very rare below the Encrinial, but common in two of the zones above it. At Eighteen Mile Creek it occurs in shale a foot below the Encrinial and in the limestone itself. At Livonia it is restricted to the Encrinial and at Cayuga Lake to a single zone about 50 feet below the Encrinial. It is a very rare fossil at Canandaigua Lake.

S. inaequistriata Conrad.

Pal. N. Y., Vol. IV., 1867, p. 93, pl. 12, figs. 6-8.

In all sections from Eighteen Mile Creek to Otsego Co., this fossil is common, and in the present faunule is represented by about 600 specimens which show no unusual characters.

S. junia Hall.

Pal. N. Y., Vol. IV., 1867, p. 108, pl. 18, figs. 3, 4.

Only one specimen which could be referred to this species was found. It has been reported from the Lower Hamilton at Eighteen Mile Creek and from the very top at Livonia and Cayuga Lake.

S. perplana Conrad.

Pal. N. Y., Vol. IV., 1867, pp. 92, 98, pl. 11, fig. 22, pl. 12, figs. 13-15.

While not so abundant as *S. inaequistriata*, this is a common species at the Canandaigua Lake locality. The specimens are all smaller than the average, the largest being 21×24 mm. The species occurs from Thedford to Otsego Co., but is rare at both limits and most common at the meridian of Cayuga Lake.

Pholidostrophia iowensis Owen.

Pal. N. Y., Vol. IV., 1867, p. 104, pl. 18, fig. 1.

In certain zones of all the sections from Thedford to Cayuga Lake, this species is common, as it is in the present faunule. Our specimens are of about the usual size.

Orthothetes chemungensis Conrad. var. *pectenacea* Hall.

Pal. N. Y., Vol. IV., 1867, p. 64, pl. 10, fig. 6.

This variety, which Schuchert has considered as a synonym for the true species *chemungensis* Conrad, is quite common in the present collection, but the specimens are rather small as compared with Hall's figures. This type was found by Cleland in zone A of the Cayuga Lake section.

O. chemungensis var. *arctistriatus* Hall.

Pal. N. Y., Vol. IV., 1867, p. 71, pl. 9.

This variety is also common in the material, and most of the specimens are rather small. The largest is 16 mm. long and 22 mm. in width. This variety occurs in both the upper and lower Hamilton in the Thedford, Eighteen Mile Creek and Cayuga Lake sections, but only above the Encrinal at Livonia.

O. bellulus Clarke.

13 Ann. Rept. N. Y., State Geol. 1895, pp. 176, 187, pl. 4, figs. 2-4.

This species was described from the Marcellus of the Livonia section and has been reported from the Marcellus at Stony Point on Lake Erie, where it occurs only a few inches above the Onondaga. It has not been found in the Hamilton previous to the present instance. The largest specimens in this collection are about 10×14.5 mm. and have 24 to 30 striæ.

Chonetes coronatus Conrad.

Pal. N. Y., Vol. IV., 1867, p. 133, pl. 21, figs. 9-12.

This species occurs in all the sections from Eighteen Mile Creek to Albany Co. It is abundant in the present material, but does not attain the size which the same species reaches in some other localities. The largest specimen is 15.4 mm. long and 23 mm. wide and the adults have from 80 to 100 striae.

Chonetes mucronatus Hall.

Pal. N. Y., Vol. IV., 1867, p. 124, pl. 20, fig. 1, pl. 21, fig. 1.

This species is common in the sections from Eighteen Mile Creek to Albany Co. At Canandaigua Lake it is abundant. The largest specimen is 11 mm. long and 13 mm. wide and the adults have from 25 to 40 striae.

Chonetes scitulus Hall.

Pal. N. Y., Vol. IV., 1867, p. 130, pl. 21, fig. 4.

This is the most abundant species in the present collection and there are at least 3,500 specimens. The adults are of the ordinary size, the largest 6×9 mm. there are usually 30 to 40 striae on the anterior margin. This is a common fossil in all zones of the sections from Eighteen Mile Creek to Cayuga Lake, but is rare in the eastern counties.

Chonetes robustus Raymond.

Am. Jour. Sci., Vol. XVII., p. 289, pl. XVII, rows 1, 2. April, 1904.

This species is not uncommon in the material. It occurs also in East Bethany, N. Y.

Strophalosia truncata Hall.

Pal. N. Y., Vol. IV., 1867, p. 160, pl. 23, figs. 12-24.

Though it has not been found in the Thedford or Eastern New York sections, this species is common in certain zones of the sections from Eighteen Mile Creek to Cayuga Lake. At Eighteen Mile Creek and Cayuga Lake it occurs below the Encinal, and at Livonia above it. It is common in the present faunule and of fair size.

Productella spinulicosta Hall.

Pal. N. Y., Vol. IV., 1867, p. 160, pl. 23.

This species is rare, and usually poorly preserved in this locality. It occurs in all three divisions (upper, Encinal, and lower Hamilton), at Eighteen Mile Creek, Livonia, and Cayuga Lake.

Rhipidomella penelope Hall.

Pal. N. Y., Vol. IV., 1867, p. 50, pl. 6.

This species is very rare at Canandaigua Lake as it is in most of the sections except for the top of the Hamilton at Thedford and Eighteen Mile Creek. It has not been reported from Eastern New York.

R. vanuxemi Hall.

Pal. N. Y., Vol. IV, 1867, pp. 40, 47, pl. 5, fig. 6, pl. 6, fig. 3.

The specimens of this species, though common, were all small. The largest is only 15 mm. long. The species occurs from Thedford to Albany Co., N. Y.

Pelycypoda.

Nuculites oblongatus Conrad.

Pal. N. Y., Vol. V, pl. 1, p. 324, pl. 47.

The largest individual of this species in the collection is 12 mm. high and 24 mm. long. The species is very rare here, and at Eighteen Mile Creek, where it occurs in only one zone. It is quite common all through the section at Cayuga Lake and occurs in most of the sections in the eastern counties.

Nuculites triqueter Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 326, pls. 47, 93.

This species occurs only as casts in the present material and is not common. The largest specimen is 7 mm. high and 9 mm. long.

The distribution is about the same as for *N. oblongatus*.

Nucula corbuliformis Hall.

Pal. N. Y., Vol. V, pt. 1, p. 319, pl. 46.

Like the above, the individuals of this species are always small and occur only as casts. The largest specimen is 5 \times 8 mm. This species has not been reported from the sections west of Canandaigua Lake, but is common all through the Cayuga Lake section, and rare in the eastern counties.

Paleoneilo constricta Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 333, pls. 48, 51.

This species which is common all through the Cayuga Lake section is rare at Eighteen Mile Creek, Livonia, Canandaigua Lake, and the eastern localities. Our specimens are rather small, the largest being 9.5 \times 15 mm.

Conocardium eboraceus Hall.

Pal. N. Y., Vol. V, p. 412.

This species is very rare in our faunule, and is represented by fragments of the shell.

Actinoptera decussata Hall.

Pal. N. Y., Vol. V, pl. 1, p. 111, pls. 17, 18, 20, 84.

This species is very rare, and only one good specimen was obtained. That is 12 mm. high and 19 mm. long. It shows the usual surface markings, the concentric ridges being high and sharp. The species is reported as rare in the Encrinial and above it at Eighteen Mile Creek and Cayuga Lake, and common in both at Livonia.

Aviculopecten exacutus Hall.

Pal. N. Y., Vol. V, pt. 1, p. 8, pl. 111.

All our specimens of this shell are small and fragmentary. The largest is 17 mm. high. The species is fairly common in the lower part of the Hamilton at Eighteen Mile Creek and in the upper part at Livonia. It is not reported further east.

Aviculopecten princeps Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 1, pls. 1, 5, 6, 24, 81.

This species is more common than any of the other lamellibranchs in the present faunule and reaches more nearly its normal size. The largest specimen is 57 mm. high and about 70 mm. long. The species is fairly common in all the sections except the extreme eastern and western ones. It is very rare at Thedford and does not occur in the eastern counties except at a few localities.

Aviculopecten scabridus Hall.

Pal. N. Y. Vol. V, pt. 1, p. 7, pl. 3.

The individuals of this species obtain a fair size at this locality. The largest is 28 mm. high. The species is common in the upper Hamilton at Livonia and is rare at Canandaigua Lake and in the lower Hamilton at Cayuga Lake. It is not reported from the other sections.

Pterineopecten intermedius Hall.

Pal. N. Y., Vol. V, pt. 1, p. 68, pls. 17, 83.

The one well preserved specimen in the collection shows the usual characters, though it is of small size, 14 mm. high.

The species is rare at Cayuga Lake, which is the only one of the sections from which it is reported.

Pterineopecten hermes Hall.

Pal. N. Y., Vol. V, pt. 1, p. 64, pl. 17.

The largest specimen of this species in the collection is 16 mm. high. It is rare here, as also at Eighteen Mile Creek and Cayuga Lake. It is not reported elsewhere.

Pterineopecten regularis Hall.

Pal. N. Y., Vol. V, pt. 1, p. 70.

There are only a few fragments representing this species, but they show the usual surface markings.

Pterineopecten conspectus Hall.

Pal. N. Y., Vol. V, pt. 1, p. 66, pl. 17.

The specimens representing this species are very small. The largest is 8×10 mm. and the others are much smaller. The species is rare at Eighteen Mile Creek and Cayuga Lake as well as at the present locality. It is not reported from the other localities.

Lyriopecten orbiculatus Hall.

Pal. N. Y., Vol. V, pt. 1, p. 42, pls. 4, 82.

A valve resembling the figures of this species was found. The species is fairly common in the upper Hamilton at Livonia.

Modiomorpha alata Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 278, pls. 37, 80.

This species is very rare here as in the other sections where it is reported, namely ; the Eighteen Mile Creek and Cayuga Lake sections.

Cypricardella bellistriata Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 485, pls. 79, 96.

The casts of this species are fairly common, though the shells are rarely preserved. The species attains its usual size.

It is found in all the sections from Eighteen Mile Creek to Albany county but is most common at Cayuga Lake.

Cypricardinia indentata Conrad.

Pal. N. Y., Vol. V, pt. 1, p. 485, pls. 79, 96.

This species is represented by some fragments which show the usual surface, but indicate individuals of small size. They are rare. The species is common at Eighteen Mile Creek and Cayuga Lake and rare at Livonia and in Otsego county.

Nassa arguta Hall.

Pal. N. Y., Vol. V, pl. 53, figs. 9-20.

Two casts appear to belong to this species. If so this is the farthest west this fossil has been found. It is common in Otsego and Albany counties.

Gastropoda.*Pleurotomaria capillaria*, Conrad.

Pal. N. Y., Vol. V, pt. 2, p. 77, pl. 20.

A few fragments of this species, showing the usual surface marking, were found. The species has been reported from Thedford, is fairly common at the base of the Hamilton and Eighteen Mile Creek, and occurs in all the sections under examination.

Cyclonema hamiltoniae Hall.

Pal. N. Y., Vol. V, pt. 2, p. 37.

A single specimen is referred doubtfully to this species.

Bellerophon leda Hall.

Pal. N. Y., Vol. V, pt. 2, p. 110, pl. 23.

Specimens of this shell are quite numerous and the largest is of about the usual size for the species. It is found in the sections from Eighteen Mile Creek to Cayuga Lake.

Platyceras bucculentum Hall.

Pal. N. Y., Vol. V, pt. 2, p. 10, pl. 3.

There are numerous small specimens in the collection which agree with Hall's figures of this species, except that they do not have the strong folds at the aperture. The species is found from Thedford to Otsego county.

Platyceras carinatus Hall.

Pal. N. Y., Vol. V, pt. 2, p. 5, pl. 2.

Most of the specimens are small, but show the characteristic features. The species is found from Eighteen Mile Creek to Albany county.

Platyceras symmetricum Hall.

Pal. N. Y., Vol. V, pt. 2, p. 9.

Specimens of this species are common, but very few show the complete aperture. The species is rare in the lower Hamilton at Eighteen Mile Creek and fairly common in the upper part of the Livonia section.

Diaphorostoma lineata Conrad.

Pal. N. Y., Vol. V, pt. 2, p. 21, pl. 10.

All the specimens are quite small, the largest being only 12 mm. in greatest diameter and showing three whorls. The species is common here as it is at Eighteen Mile Creek, Livonia, and Cayuga Lake. At Thedford it is rare, although it occurs all through the section.

Loxonema hamiltoniae Hall.

Pal. N. Y., Vol. V, pt. 2, p. 45, pl. 13.

Specimens of this species are of about the usual size and appearance. The species is abundant above the Encinal at Livonia and occurs all through the section at Cayuga Lake.

Styliola, sp.

A few specimens of some species of this genus were observed in the blocks before etching.

Tentaculites bellulus Hall.

Pal. N. Y., Vol. V, pt. 2, p. 169, pls. 31, 31A.

Individuals of this species are very numerous and show some variation in the annulations. The species is fairly common at Livonia and very rare at Cayuga Lake.

Hyolithes acilis Hall.

Pal. N. Y., Vol. V, p. 2, p. 197, pls. 32, 32A.

Three small specimens represent the apical end of this species. It is found rarely throughout the Cayuga Lake section.

Platyceras thetys Hall.

Pal. N. Y., Vol. V, pt. 2, p. 8.

There are a few small, not very perfectly preserved specimens belonging to this species. It occurs at Livonia and in Albany county.

Cephalopoda.*Orthoceras*.

The siphuncle of some small species of *Orthoceras* was obtained.

Crustacea.*Primitopsis punctilifera* Hall.

13 Ann. Rept. N. Y. State Mus. Nat. Hist., p. 92.

A few specimens are referred to this species. It is common at Thedford and rare throughout the section at Eighteen Mile Creek.

Kirkbya parallela Ulrich.

Jour. Cinn. Soc. Nat. Hist., Vol. XIII, p. 192, pl. 15, figs. 2a, b.

This species is fairly common.

Strepula sigmoidalis Jones.

Quar. Jour. Geol. Soc., Vol. XLVI, p. 11.

This is one of the most common of the ostracods in this collection.

Isochilina lineata Jones.

Quart. Jour. Geol. Soc., Vol. 46, p. 21, pl. 2, figs. 5a, b, 8a, b.

Only a few specimens found.

I. fabacea Jones.

Quart. Jour. Geol. Soc., Vol. XLVI, p. 22, pl. 2.

This species is also very rare.

Primitia seminulum Jones.

Ann. Mag. Nat. Hist., Ser. V, Vol. XVII, p. 413, pl. 14.
There are several specimens of this species.

Octonaria stigmata Ulrich.

Jour. Cinn. Soc. Nat. Hist., Vol. XIII, p. 193, pl. 16, figs. 8a, b.
Rather uncommon.

Ctenobolina papillosa Ulrich.

Jour. Cinn. Soc. Nat. Hist., Vol. XIII, p. 186, pl. 15, figs. 8a-c.
A few specimens are with some doubt referred to this species.

Beyrichia kolmodini Jones.

Jour. Cinn. Soc. Nat. Hist., Vol. XIII, p. 190, pl. XIV, figs. 1a-c.
This species is common.

Halliella retifera Ulrich.

Jour. Cinn. Soc. Nat. Hist., Vol. VII, p. 185, pl. 15, figs. 5a-c.
Another rare species.

Moorea bicornuta Ulrich.

Jour. Cinn. Soc. Nat. Hist., Vol. XIII, p. 191, pl. 16, figs. 4a-c.
Only a couple of specimens of this ostracod were found.

Ostracoda sps.

Several other species of ostracods were obtained, but have not yet been identified.

Proetus rowi Green.

Pal. N. Y., Vol. VII, p. 119, pls. 21, 23.

A few separated head and tail shields of this species were found. They were of small size. The species occurs rarely in the sections from Eighteen Mile Creek to Cayuga Lake, and a single specimen has been found at Worcester in Otsego county.

Cyphaspis ornata Hall.

Illust. Dev. Foss., 1876, pl. 21.

A single fragment of a specimen of this species was found.

Dipleura dekayi Green.

Pal. N. Y., Vol. 7, p. 7, pls. 2-5.

Portions of several tail shields were obtained. The species occurs from Eighteen Mile Creek to Otsego Co.

Phacops rana Green.

Pall. N. Y., VII, p. 19, pls. 7, 8, 8A.

Specimens of this species are quite common, although usually of small size. The species is common in all sections except in the eastern counties where it is rare except locally.

Cypræus boothi Green.

Pal. N. Y., Vol. VII, p. 42, pls. 16, 16a.

Specimens of this species were common. The species is common from Thedford to Otsego county.

REFERENCES.

- BEECHER, C. E. Origin and Significance of Spines. Am. Jour. Sci. (4), VI, 1898.
Development of the Brachiopoda. Am. Jour. Sci. (3), Vol. 42, 1891, and
Vol. 44, 1892.
Some Correlations of Ontogeny and Phylogeny in the Brachiopoda. Am. Nat.,
July, 1893.
AND CLARKE, J. M. The Development of some Silurian Brachiopoda.
Memoirs of the New York State Museum, Vol. 1, No. 1, Oct. 1889.
AND SCHUCHERT, C. Development of the Brachial Supports in *Dielasma* and
Zygospira. Proc. Biol. Soc. Wash., Vol. 8.
CLARKE, J. M. A Brief Outline of the Geological Succession in Ontario Co., New
York. Ann. Rept. N. Y. State Geol., 1884.
The Succession of Fossil Faunas in the Section of the Livonia Salt Shaft. 13th
Ann. Rept., New York State Geol., 1894.
The Marcellus Limestone of Central and Western New York. Bull. N. Y. State
Museum, No. 49, Dec., 1901.
CLELAND, H. F. A Study of the Fauna of the Hamilton Formation of the Cayuga
Lake Section in Central New York. Bull. of the U. S. Geol. Survey, 206,
1903.
CUMINGS, E. R. Orthothetes minutus n. s. from the Salem Limestone of Harrods-
burg, Ind. Am. Geol., Vol. XXVII, Mar. 1901.
The Morphogenesis of Platystrophia. A Study of the Evolution of a Paleozoic
Brachiopod. Am. Jour. Sci., Vol. XV, 1903.
GRABAU, A. W. The Faunas of the Hamilton Group of Eighteen Mile Creek and
Vicinity in Western New York. 16th Ann. Rept., State Geol. N. Y., 1898.
GRABAU, A. W., AND SHIMER, H. W. The Thedford (Ont.) Section. Bull. Geol.
Soc. Am., Vol. 13, pp. 149-186, June, 1902.
HALL, JAMES, AND CLARKE, J. M. Brachiopoda. Pal. N. Y., Vol. 8, Parts 1
and 2, 1892.
EHLERT, D. P. Ann. des Sciences Geologic, Vol. XIX.
MORSE, E. S. Early Stages of *Terebratulina septentrionalis*. Mem. Bos. Soc. Nat.
Hist., II, Pt. 1, No. 1, 1871.
Observations on the Living Brachiopoda. Mem. Bos. Soc. Nat. Hist., V, No.
8, 1902.
PROSSER, C. S. The Devonian System of Eastern Penn. and New York. U. S.
Geol. Survey, Bull. 120, 1894.

- The Classification and Distribution of Hamilton and Chemung Series of Central and Eastern New York. 15th Ann. Rept. State Geol. N. Y., 1895.
- RAYMOND, P. E. The Developmental Changes in some Common Devonian Brachiopoda. Am. Jour. Sci. (4), Vol. XVII, 1904.
- SCHUCHERT, C. Synopsis of Am. Foss. Brachiopoda. Bull. U. S. Geol. Survey, No. 87, 1897.
- TALBOT, MIGNON. A contribution to a list of the Fauna of the Stafford Limestone of New York. Am. Jour. Sci., Vol. XVI, 1903.
- WILLIAMS, H. S. Shifting of Faunas as a Problem of Stratigraphic Geology. Bull. Geol. Soc. Am., Vol. XIV, pp. 177-190. Apr., 1903.
- Correlation of Geological Faunas: A Contribution to Devonian Paleontology. Bull. 210, U. S. Geol. Surv.

EXPLANATION OF PLATES.¹

PLATE I.

Pholidops hamiltoniae Hall.

Rows 1 and 2. Series of dorsal valves. $\times 2$.

Rows 3 and 4. Series of ventral valves. $\times 2$.

PLATE II.

Pholidops oblate Hall.

Rows 1 and 2. Series of dorsal valves. $\times 2$.

Rows 3 and 4. Series of ventral valves. $\times 2$.

PLATE III.

Row 1. Partial series of *Stropheodonta perplana* Conrad; ventral valves. Specimens Nos. 3-9 show well the mucronate cardinal extremities of the adolescent individuals.

Rows 2-4. Series of *Stropheodonta inequistriata* Conrad; ventral valves, showing the shells in neanic, ephebic, and gerontic stages.

PLATE IV.

Chonetes scitulus Hall.

Rows 1 and 2. Series of ventral valves. $\times 2$.

Rows 3 and 4. Series of dorsal valves: interior view. $\times 2$.

Specimens Nos. 1 and 2 of Row 1, and Nos. 1 and 2 of Row 3, show the ventral sinus and dorsal fold of the very young stages. Most of the specimens in Row 4 show the brachial scars.

PLATE V.

Row 1. Partial series of *Orthothetes chemungensis* var. *pectenacea* Hall; dorsal valves. $\times 2$.

Row 2. Partial series of *Orthothetes chemungensis* var. *arctistriatus* Hall; dorsal valves. $\times 2$.

¹ Unless otherwise stated, the figures are natural size.

Row 3. Partial series of *Orthothetes bellulus* Clarke; dorsal valves. $\times 2$.

Rows 4 and 5. Series of *Chonetes mucronatus* Hall; ventral and dorsal valves. $\times 2$.

Row 6. Series of *Cyrtina hamiltonensis* Hall; dorsal valves. $\times 2$.

PLATE VI.

Rows 1 and 2. Partial series of *Spirifer mucronatus* Conrad; dorsal valves.

Row 3. Series of *Chonetes coronatus* Conrad; ventral valves, exterior.

Row 4. The same; dorsal valves, interior.

PLATE VII.

Rows 1 and 2. Series of *Chonetes robustus* Raymond; ventral and dorsal valves.

$\times 2$.

Rows 3 and 4. Series of *Strophalosia truncata* Hall; dorsal and ventral valves.

$\times 2$.

PLATE VIII.

Tropidoleptus carinatus Conrad.

Rows 1 and 2. Series of ventral valves.

Rows 3 and 4. Series of dorsal valves.

NOTE.—A bulletin of the New York State Museum (number 63), on "A Stratigraphic and Paleontologic Map of the Canandaigua Lake and Naples Quadrangles" has been issued since this article has been in the printer's hands. In it, the authors, Dr. John M. Clarke and D. Dana Luther, refer to the so-called encrinial limestone of the region as the Tichenor limestone and give the following section (in descending order).

- | | | |
|--------------------------|-------|---------------|
| 9. Tully limestone | | about 3 feet. |
| 8. Moscow shale..... | | 125 feet. |

Intercalated in this, about fifty feet below the Tully and seventy-five feet above the Tichenor, is the Menteth limestone, a foot in thickness, in which the fossils are silicified.

- | | | |
|----------------------------|-------|-----------------|
| 7. Tichenor limestone..... | | 1 foot. |
| 6. Canandaigua shale..... | | about 125 feet. |
| 5. Skeneateles shale..... | | 125 feet. |
| 4. Cardiff shale..... | | about 50 feet. |
| 3. Stafford limestone..... | | 1 foot (?) |
| 2. Marcellus shale..... | | about 50 feet. |
| 1. Onondaga limestone. | | |

The writer furnished Dr. Clarke with a list of the fossils identified from the silicified material here discussed and it is printed, with some additions by Dr. Clarke in the above bulletin. The authors must, however, be in error in assigning the list to the Menteth limestone alone, for I was assured by the late Dr. Beecher, whose skill as a collector is universally recognized, that he had obtained the material from several different layers through a range of some seventy-five feet above the encrinial limestone, and during the process of etching I remember that he was particularly interested in observing the relative value of the various layers as producers of fine fossils.

The different blocks used differed greatly both in lithologic character and in fossil contents, and must have been derived from various layers.